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RESEARCH AND DEVELOPMENT TECHNICAL REPORT

ECOM 0270-F

RANGEFINDER, LASER AN/GVS-5 ( )

FINAL REPORT

By

J. WOODWARD - S.WALDSTEIN

JUNE 1977

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This AN/GVS-5(V) Final Technical Report documents the two years of effort expended by RCA Corporation for the United States Army Electronic Command. This report describes effort which occurred subsequent to submission of the Design Plan which detailed the analytical effort, breadboarding, and planned tests.

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This report makes frequent references to the Design Plan and describes the differences in the final product. Pertinent excerpts from the Design Plan, which are referenced in this report, are included in Appendix A of this report.

The principal items discussed are the:

(1) Hand Held Laser Rangefinder
(2) Special Test Equipment, and
(3) Azimuth - Elevation Head and Tripod.

The performance characteristics or typical parameters are shown to meet the requirements of the development specification. Detailed definition of the hardware is fully documented in drawing sets.

The results of performance and environmental tests are presented in detail, and finally, changes are recommended for future consideration.

RANGEFINDER, LASER AN/GVS-5( )
FINAL REPORT
JULY 1974 TO MAY 1976

Contract No. DAAB07-74-C-0270
DA Project No. 1E7 64723 DL 71 03 01

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Prepared by

J. Woodward and S. Waldstein

June 1977

RCA/Government and Commercial Systems
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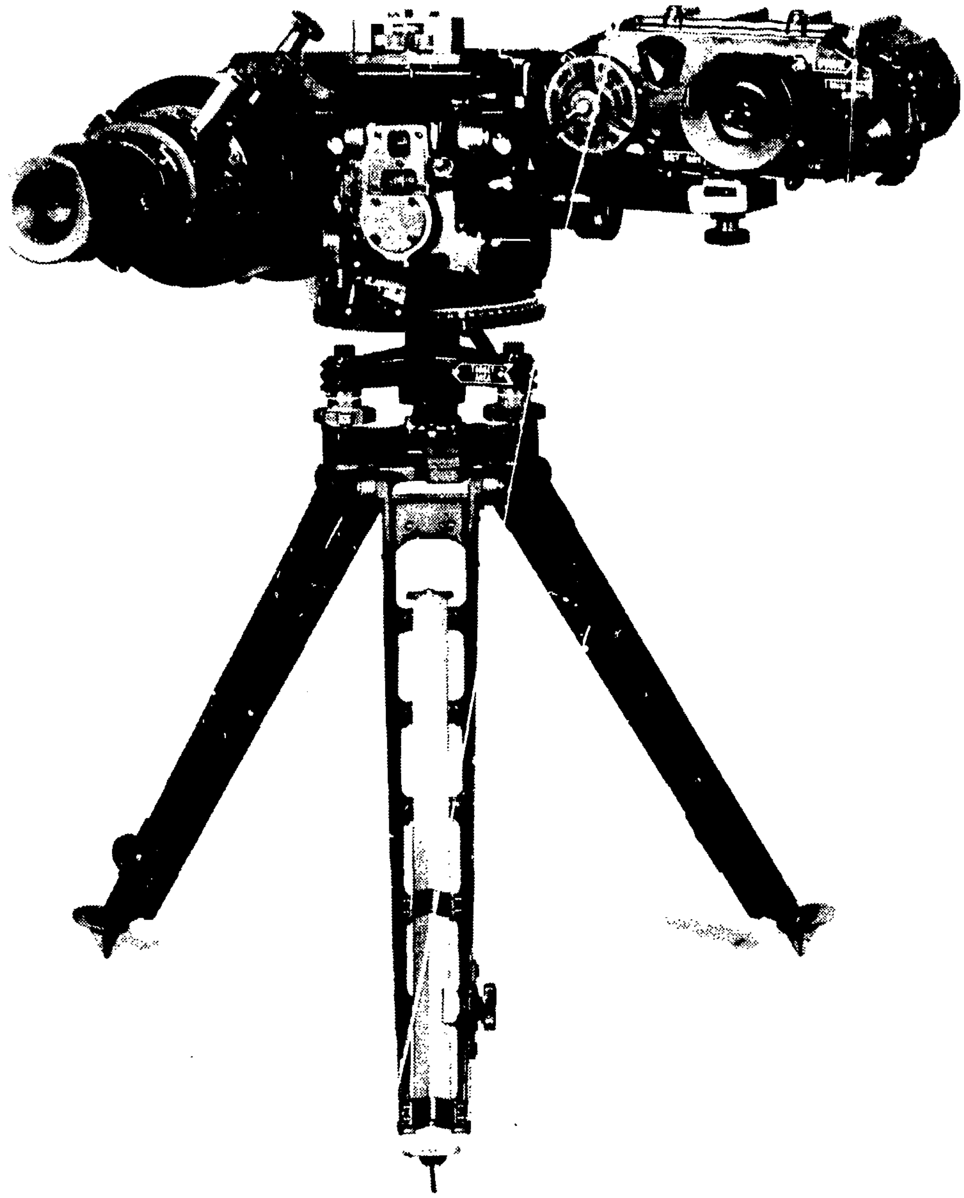
Burlington, Massachusetts

For
U.S. Army Electronics Command, Fort Monmouth, New Jersey



Frontispiece. AN/GVS-5( ) Laser Rangefinder Mounted on Tripod with Night Vision Sight

ABSTRACT

This AN/GVS-5 (V) Final Technical Report documents the two years of effort expended by RCA Corporation for the United States Army Electronics Command. This report describes effort which occurred subsequent to submission of the Design Plan which detailed the analytical effort, breadboarding and planned tests.

This report makes frequent references to the Design Plan and described the differences in the final product. Pertinent excerpts from the Design Plan, which are referenced in this report, are included in Appendix A of this report.

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The results of performance and environmental tests are presented in detail, and finally, changes are recommended for future consideration.

FOREWORD

This AN/GVS-5 (V) Final Technical Report was prepared by RCA Automated Systems Division, Burlington, Massachusetts, under U.S. Army Contract No. DAAB07-74-C-0270, Project No. 1E7 64723 DL 71 03 01, sponsored by the United States Army Electronic Command, Forth Monmouth, New Jersey.

The report covers the effort of many members of the RCA technical and manufacturing staff in the ASD plant with the support of the RCA Central Engineering Group, Camden. Significant contributions were made by Leitz, Canada Ltd., Wilmore Electronics Co., Inc., RCA Ltd., Canada, RCA Solid State Technology Center, Somerville, N.J., and in the early phase at the program by IBM, Federal Systems Div., Owego, N.Y.

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SECTION 1

INTRODUCTION

1.1 SCOPE OF REPORT

This report covers the technical work accomplished under USAECOM Contract No. DAAB-07-74-C-0270 as related to and reflected in the Laser Rangefinder Set, AN/GVS-5( ), hardware described below. In particular, the report reflects the results of effort subsequent to the submission of the Design Plan (CDRL Sequence No. H001) for the Laser Rangefinder and for the Laser Rangefinder Mount (AZ-EL Head). The planned design and the analytical effort, breadboarding, and tests which substantiated the planned design were reported in detail in the Design Plan. This report makes frequent reference to the Design Plan and describes the differences between the final hardware and that presented in the Design Plan and the reasons for the differences. Duplication of the information contained in the many hundreds of pages of the Design Plan is avoided insofar as possible.

1.2 SUMMARY DESCRIPTION OF EQUIPMENT

The principal item of equipment developed, fabricated, and tested on the contract was the Laser Rangefinder MX-9838( )/GVS-5( ), frequently referred to as the Hand Held Laser Rangefinder (HHLR). The other items of the AN/GVS-5( ) Laser Rangefinder set are used to protect, mount, power, test or support the HHLR.

1.2.1 Hand Held Laser Rangefinder

The Hand Held Laser Rangefinder, shown in Figure 1-1, is designed to be held like a binocular and sighted upon the desired target through its seven power telescope. Depressing and holding the FIRE pushbutton on the control panel causes the range to target to be measured electronically and displayed in the telescope in the lower portion of the sighting telescope reticle. The range to the target, in meters to the nearest ten meters, is shown directly by a four-digit, seven-segment light emitting diode (LED) display. The unit is powered by a replaceable, rechargeable Nickel Cadmium battery which is installed through a screw closure in the left-hand portion of the control panel. A fully charged battery provides over 400 range measurements in normal usage.

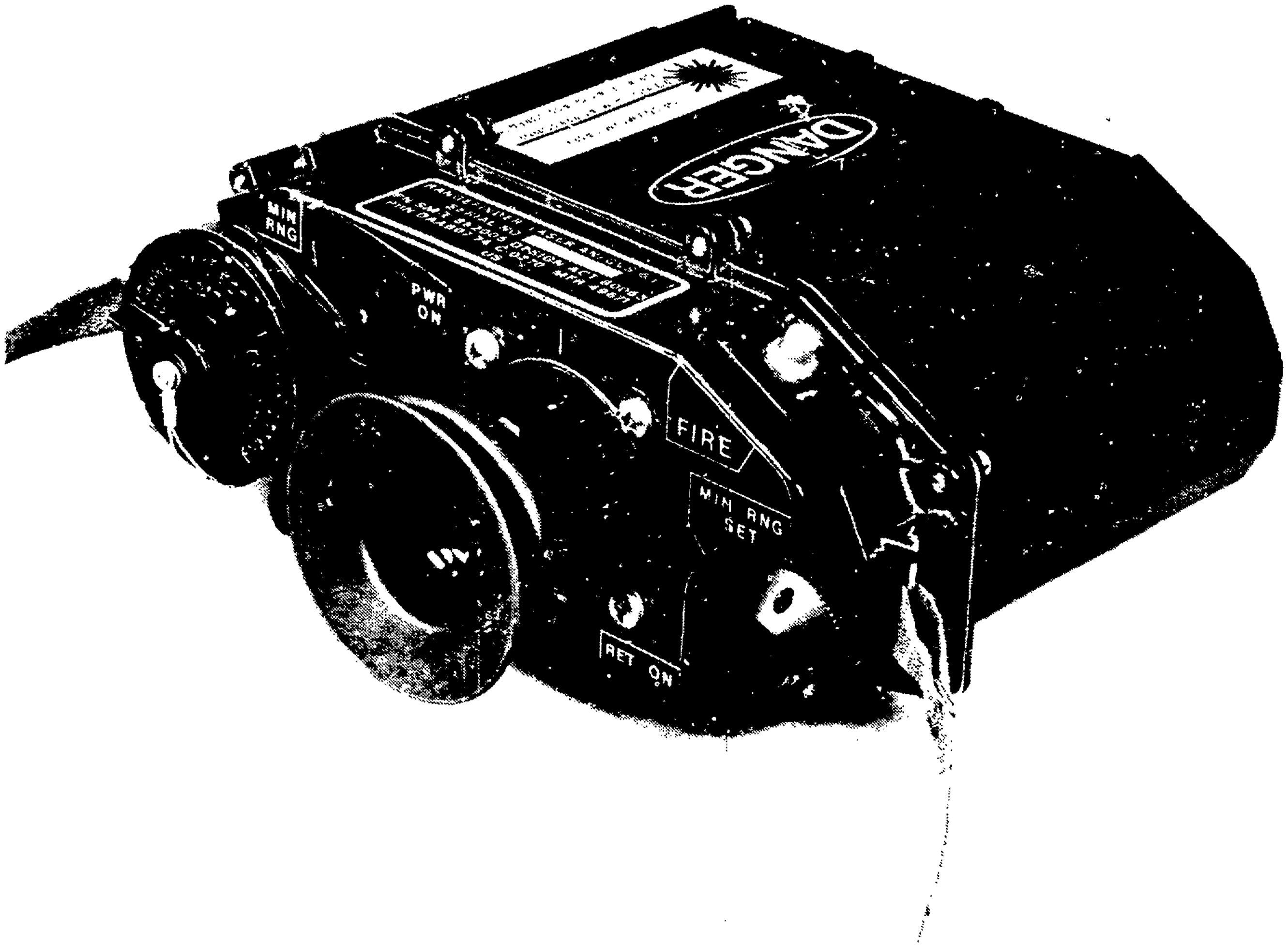

Figure 1-1. Laser Rangefinder MX-9838( )/GVS-5

Other features of the HHLR are a minimum range gate to preclude ranging to interfering objects near to the user. The setting of this gate, adjustable from 200 to 5000 meters, is displayed by the range display when the MIN RNG ON button is depressed and is controlled by the MIN RNG SET potentiometer. A reticle light for dusk or nighttime use is turned on by the RET ON pushbutton and adjusted by the RET BRT potentiometer. A POWER ON-OFF switch enables the other functions, although no power is consumed unless one of the three push-buttons is held down. The operator also has a diopter adjustment of the tele-scope eyepiece to adjust focus for his eye accommodation. A neck strap, left hand strap, and removable optical window cover are provided. A precision pad on the bottom center of the panel contains a 0.250" -20 female thread for mounting the HHLR to a tripod or other mount.

The HHLR provides range to targets between 200 and 9990 meters under most conditions when the targets are visible within the one mil central field of the sighting telescope. If an object in addition to the desired target is within the one mil field of view during ranging a multiple target light to the right of the range display is illuminated. A second light to the left of the range display warns of a battery in need of recharging. The HHLR may also be operated from external power supplied by a military vehicle electrical system. The Special Purpose Electrical Cable Assembly, CX-13021( )/GVS-5 plugs into the HHLR in place of the battery, connects the HHLR to vehicle power and conditions the power for use in the HHLR.

1.2.2 Special Test Equipment

A test set specifically designed for rapid go no-go operational checking of the HHLR is the other active electro-optical item developed and supplied on the contract. The Laser Rangefinder Test Set TS-3620( )/GVS-5 (Figure 1-2) is contained in a combination case with cable storage in the cover. Powered from a 60 Hz, 120V a-c supply, the test set, commonly referred to as the STE, can detect HHLR laser output, supply an optical stimulus to the HHLR receiver, and demonstrate correct operation of the HHLR electronics. A mounting bracket carried in the STE cover supports the HHLR under test in correct relationship to the STE optical ports. The STE also provides signals and monitor points for troubleshooting so that problems can be isolated to a specific HHLR module.

1.2.3 Azimuth-Elevation Head and Tripod

The third major hardware item developed on this contract is the Laser Rangefinder Mount MT-4880( )/GVS-5 commonly referred to as the Azimuth-Elevation Head (Figure 1-3). The assembly of the Az-El Head (AEH) and tripod is used in the Artillery Complement of the AN/GVS-5( ) to provide stable mounting and to add azimuth and elevation readout capability to the rangefinding and sighting functions. It also provides support for several types of night vision devices which can be boresighted with the HHLR to enhance nighttime operational capability.

1.2.4 Laser Rangefinder Characteristics

Performance characteristics or typical parameters of the HHLR, listed in Table 1-1, are representative of the hardware developed in the course of this program to meet the requirements of the development specification EL-CP5100-0001A.

1.2.5 Laser Rangefinder Set AN/GVS-5(V)

The items comprising the Infantry and Artillery Complements of the AN/GVS-5( ) are listed in Table 1-2.

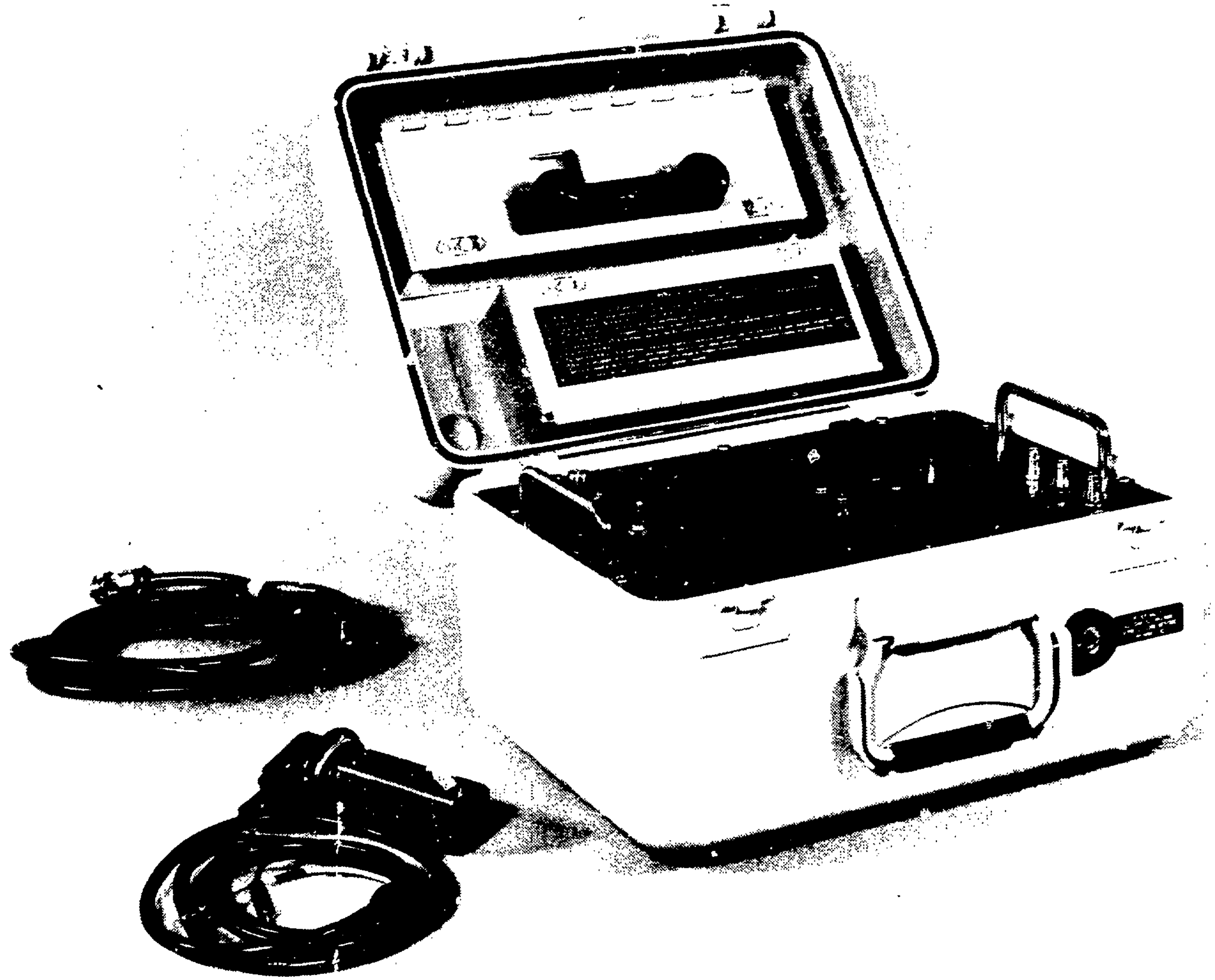

Figure 1-2. Laser Rangefinder Test Set TS-3620( ) GVS-5

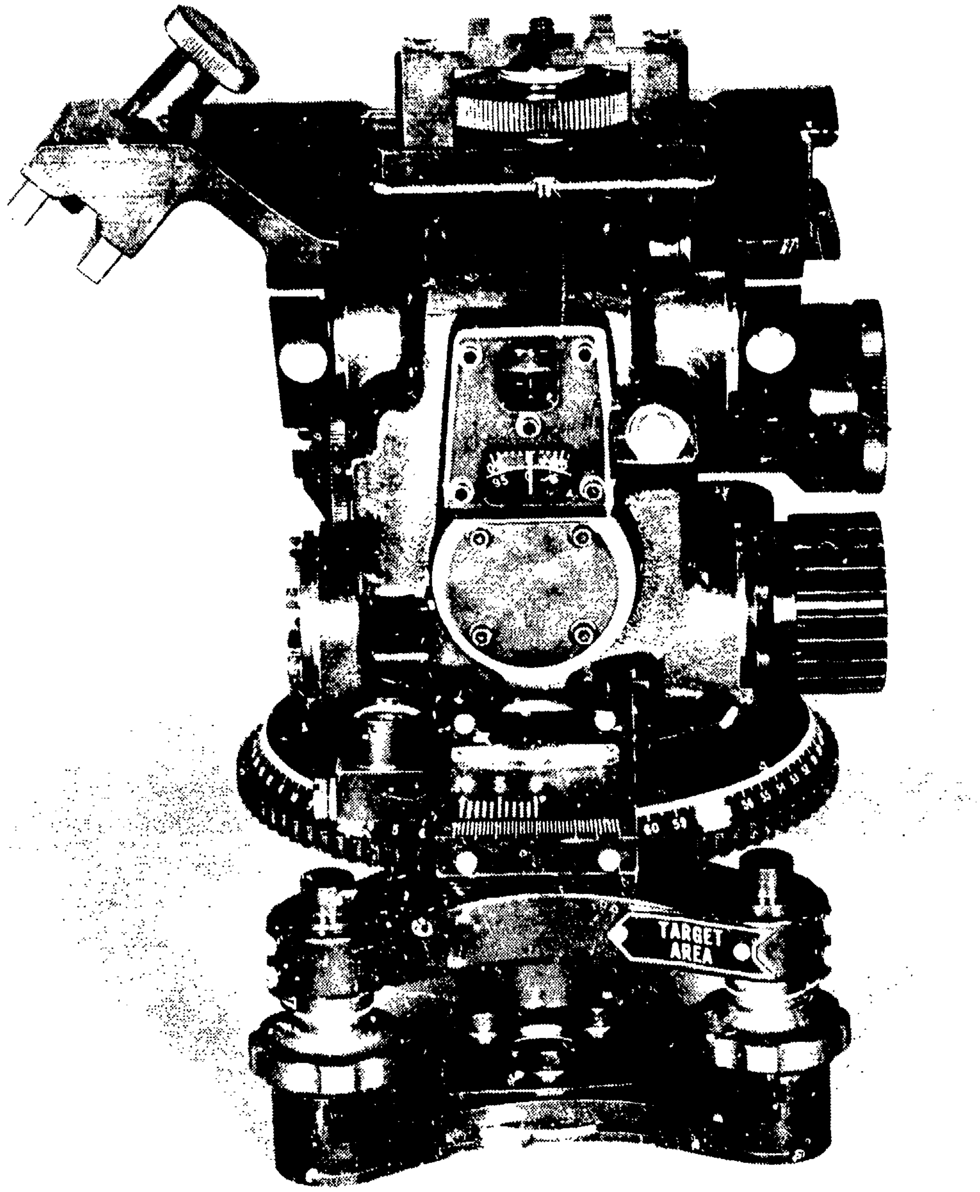

Figure 1-3. Laser Rangefinder Mount MT-4880( )/GVS-5

Table 1-1. Typical Characteristics MX-9838( )/GVS-5

Parameter	Value
Maximum Range	9990 meters
Minimum Range	$\leqq$ 200 meters
Range Resolution	$\pm$ 10 meters
Range Accuracy (R.S.S.)	10 meters
Minimum Range Gate Continuous Adjustment Range	$\leqq$ 200 meters to 5000 meters
Sight Field of View	7°
Reticle - Crosshairs and/or grid	5 Mil fiducials, 10 Mil numeric, 1 Mil central circle
Resolution	7 arc seconds, on axis
Receiver/Sight Aperture	50 mm diameter
Receiver Field of View	1 Mil
Receiver Bandwidth	20 nm
Receiver Sensitivity	2 nW/cm^2
False Alarm Rate (internal noise)	< 0.01
Transmitter Aperture	18 mm diameter
Transmitter Power	2 MW in 1.0 Mil beam
Transmitter Pulse Width	6 ns
Ranging Duty Cycle	96/hour (continuous)
Recycle Time	$\leq$ 1 second (for Edc >20V)

Table 1-1. Typical Characteristics MX-9838( )/GVS-5 (Cont.)

Parameter	Value
Power Source (Plus-in BB-516( )/U or external)	20 - 30 V. d-c 1A for 1 second, ranging < 0.1A display
Range Display	4 digit, 7 segment LED, image in reticle plane
Other Displays	Multiple Target LED, Battery Low LED
Controls	Power On Switch - Rotary Min. Range Switch - Pushbutton Min. Range Rheostat - Rotary Reticle Light Switch - Pushbutton Reticle Light Rheostat - Rotary Range (Fire) Switch - Pushbutton
Weight	< 5 lb. w/battery

Table 1-2. AN/GVS-5( ) Items

Item	Common Name	Official Nomenclature
1	GVS-5 Set	Rangefinder, Laser AN/GVS-5( ) includes the following:
2	HHLR (LRF)	1 ea Rangefinder, Laser MX-9838( )/GVS-5
3	LRF Transit Case	1 ea Case, Transit, Laser Rangefinder CY-7535( )/GVS-5
4	LRF Carrying Case	1 ea Case, Field, Laser Rangefinder CY-7536( )/GVS-5
5	AN/PVS-4, AN/TVS-5 Mounting Bracket	0-1 ea Mount, Adapter, MT-4832( )/GVS-5
6	External Power Cable	0-1 ea Cable Assembly, Special Purpose Electrical CX-13021( )/GVS-5
7	AZ-EL Head/Tripod	Mounting Group, Azimuth-Elevation 0A-8933( )/GVS-5
8	AZ-EL Head (AEH)	0-1 ea Mount, Azimuth-Elevation, Laser Rangefinder MT-4880( )/GVS-5
9	AEH Carrying Case (hard)	0-1 ea Case, Field, AZ-EL Mount CY-7667( )/GVS-5
10	AEH Carrying Case (soft)	0-1 ea Case, Field, AZ-EL Mount CY-7668( )/GVS-5
11	AEH Transit Case	0-1 ea Case, Transit, AZ-EL Mount CY-7669( )/GVS-5
12	AEH Mounting Bracket	0-1 ea Mounting Bracket, Laser Rangefinder MT-4881( )/GVS-5

Table 1-2. AN/GVS-5( ) Items (Cont.)

Item	Common Name	Official Nomenclature
13	Tripod	0-1 ea Tripod SM-D-882365
14	Shelf Mount	0-1 ea Shelf Mount SM-D-882391
15	Special Test Equipment (STE)	Test Set, Laser Rangefinder TS-3620( )/GVS-5
16	Battery Charger	Battery Charger PP-7286( )/U
17	Infantry Complement consists of the following:	Rangefinder, Laser AN/GVS-5( ) includes the following:
18	HHLR (LRF)	Rangefinder, Laser MX-9838( )/GVS-5
19	LRF Transit Case	Case, Transit, Laser Rangefinder CY-7535( )/GVS-5
20	LRF Carrying Case	Case, Field, Laser Rangefinder CY-7536( )/GVS-5
21	AN/PVS-4, AN/TVS-5 Mounting Bracket	Mount, Adapter MT-4832( )/GVS-5
22	External Power Cable	Cable Assembly, Special Purpose Electrical CX-13021( )/GVS-5
23	Artillery Complement consists of the following:	Rangefinder, Laser AN/GVS-5( ) includes the following:
24	HHLR (LRF)	Rangefinder, Laser MX-9838( )/GVS-5

Table 1-2. AN/GVS-5( ) Items (Cont.)

Item	Common Name	Official Nomenclature
25	LRF Transit Case	Case, Transit, Laser Rangefinder CY-7535( )/GVS-5
26	LRF Carrying Case	Case, Field, Laser Rangefinder CY-7536( )/GVS-5
27	External Power Cable	Cable Assembly, Special Purpose Electrical CX-13021( )/GVS-5
28	AZ-EL Head (AEH)	Mount, Azimuth-Elevation Laser Rangefinder MT-4880( )/GVS-5
29	AEH Carrying Case (hard)	Case, Field, AZ-EL Mount CY-7667( )/GVS-5
30	AEH Carrying Case (soft)	Case, Field, AZ-EL Mount CY-7668( )/GVS-5
31	AEH Transit Case	Case, Transit, AZ-EL Mount CY-7669( )/GVS-5
32	AEH Mounting Bracket	Mounting Bracket, Laser Rangefinder, MT-4881( )/GVS-5
33	Tripod	Tripod SM-D-882365
34	Shelf Mount	Shelf Mount SM-D-882391

1.3 RELATED DOCUMENTS

1.3.1 Design Plan

The planned design of the hardware developed under this contract is described, with supporting analyses in the Design Plan, Contract Document H001(P/O CLIN 0013): "AN/GVS-5( ) Preliminary Design and Visualization Data, Design Plan," in four volumes. Volume IV describes the Azimuth-Elevation Head, Volumes I - III describe the HHLR and other accessories.

For purposes of this report the Design Plan is the principal reference.

1.3.2 Development Specifications

The development specifications for the equipment are:

(1) "ECOM Development Specification, EL-CP5100-0001A, 15 September 1972, Rangefinder, Laser AN/GVS-5( )," and

(2) "ECOM Development Specification, EL-CP5112-001A, 2 April 1974, Azimuth Elevation Head for AN/GVS-5( )."

1.3.3 Drawings

Detailed definition of the hardware is given by drawing sets under the following top drawings:

(1) Laser Rangefinder Set Assembly, AN/GVS-5
DWG. NO. SM-D-852000
DL-852100

(2) Azimuth Elevation Mount Set Assembly
DWG. NO. SM-D-852475
DL-852466

(3) Test Set Assembly
DWG. NO. SM-D-852360
DL-852457

SECTION 2

LASER RANGEFINDER SET AN/GVS-5( ) DESIGN IMPLEMENTATION

2.1 LASER RANGEFINDER MX-9838( )/GVS-5

2.1.1 Packaging

2.1.1.1 HHLR Housing

The HHLR (Figure 2-1) is contained within a two piece housing consisting of the Control Panel and Cover Assemblies. Together they form a protective enclosure for the electronic circuitry and the laser optics.

The HHLR housing is accurately described in the Design Plan Volume I paragraph 2.1.1, pp 2-1 thru 2-13, except for a few minor differences which are discussed below. Updated Figures 2-2, 2-3 and 2-4 supersede Figures 2-1, 2-2, and 2-3 of the Design Plan.

The Control Panel is the prime structure of the equipment. It supports all of the parts, components, and subassemblies that form an operable device. From a structural viewpoint, the Control Panel is designed to provide adequate load paths to prevent permanent deformation under conditions of handling shock. It mounts all the controls and other functional elements necessary for operation. Control placement is dictated primarily by human engineering requirements and secondarily by packaging convenience.

It is investment cast from Type A356 aluminum. Die castings are not specified primarily because of weight, i.e., thinner cast walls are available in investment castings. The Control Panel is finished with an electroless nickel plate. External surfaces are covered by a primer and an olive drab semi-gloss aliphatic polyurethane solar-reflecting top coat. Figure 2-2 is an updated view of the Control Panel.

The Cover Assembly, shown in Figure 2-3, makes up the other part of the housing. Besides its functional use as an enclosure, it supports the optical windows and a strap retention pin. Additionally, it has been human engineered to form a comfortable hand grip with finger holds.

Being primarily an enclosure, the cover need be only of sufficient rigidity to withstand the highest pressure differential and maximum handling and shock loads to reduce weight to a minimum. Except for the mounting/sealing flange and the window retention features, the basic metal thickness in aluminum is 0.035 inch nominal. To provide the required rigidity and the finger holds, hat sections were formed in the skin. These add very little weight while greatly increasing structural stiffness.

The cover has been modified so that in addition to being held in place by elastomeric bonding, as shown in the Design Plan, the windows are retained by threaded lock rings. The lock rings take most of the stress resulting from pressure differential across the windows and thus minimize the stress on the elastomer and assure effective sealing by the elastomer. A one-piece protective cover is used over the windows.

The electrically conductive elastomeric EMI seal at the front of the Optical Assembly has been deleted from the system. It was determined to be unnecessary for EMI attenuation. The rubber light shield, which is retained, is shaped to permit a large variation in its assembled height. It is bonded to the retaining ring of the receiver objective lens and, at assembly, is engaged by an annular ring in the cover. By this means it acts as a light seal and prevents existing laser light or flash lamp radiation from entering the receiver portion of the telescope. The light shield is shown in Figure 2-4.

When the HHLR is purged, all of the nitrogen gas is piped directly into the sealing cavity, from the purge port in the cover. The gas then flows through a slot in a plenum into the main body of the rangefinder and is finally exhausted through the purge port in the control panel. This assures purging of the receiver objective lens while maintaining the light shield effectiveness.

2.1.1.2 <u>Electronic Packaging</u>

The HHLR is so packaged that removal of the cover leaves a completely operable assembly to facilitate manufacturing test and maintenance. Two microswitches acting as safety interlocks require overriding for operation.

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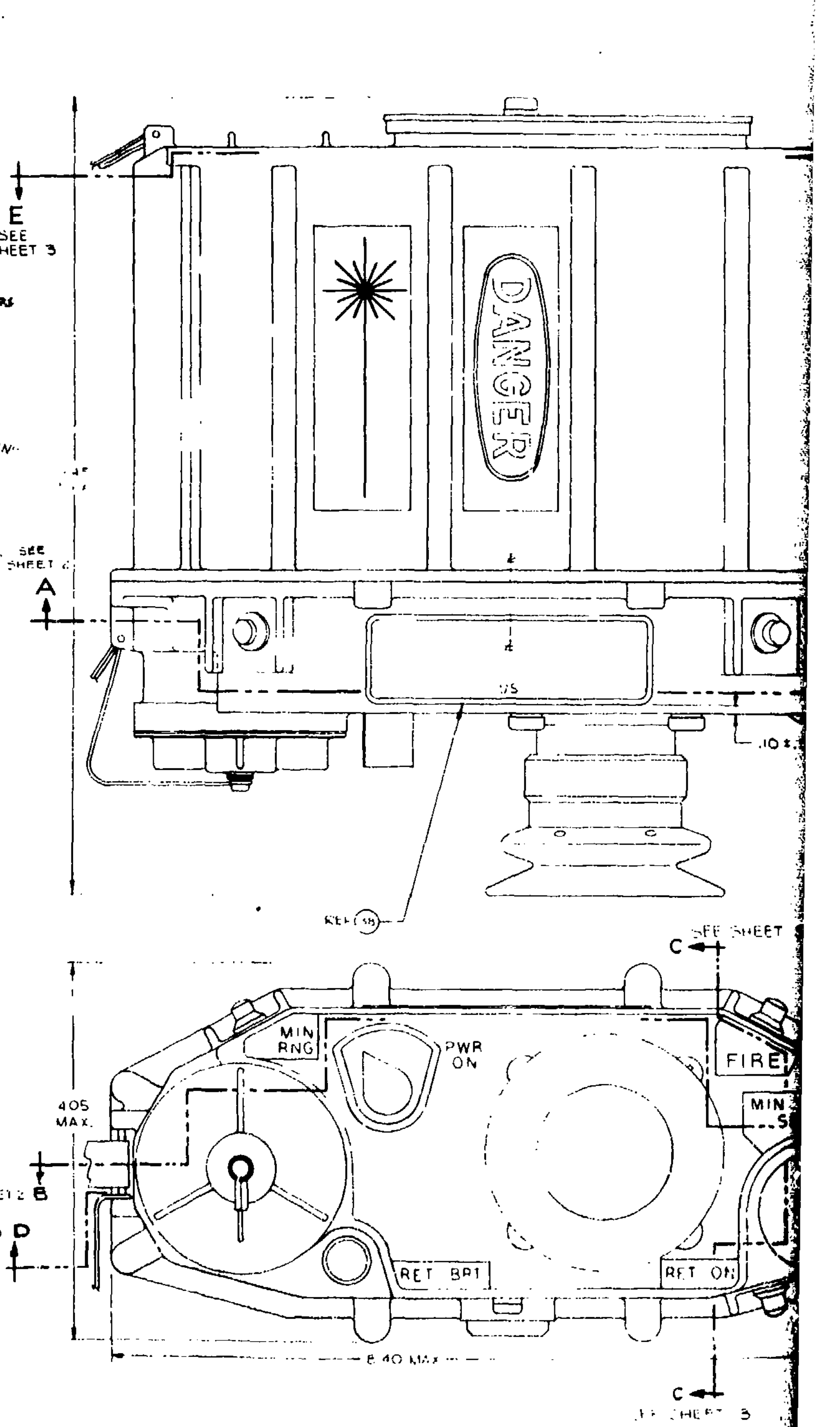
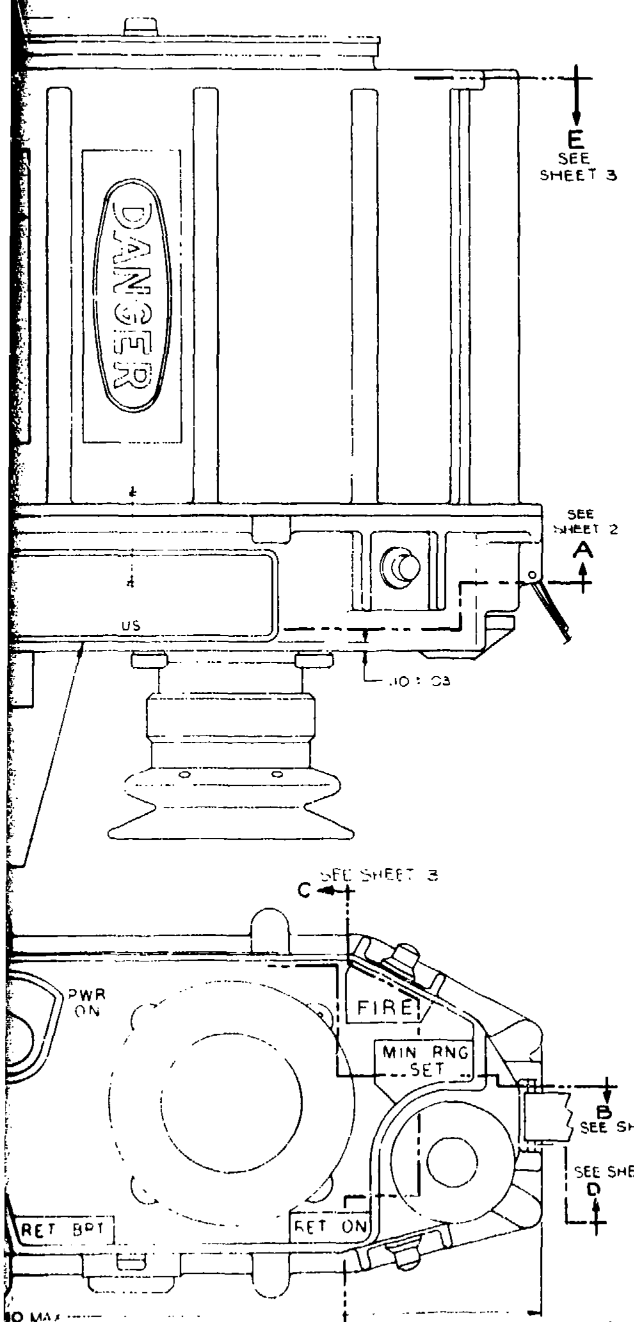
NOTES:
1. FOR SCHEMATIC DIAGRAM SEE SM-D-852033.
2. SOLDER PER MIL STD-454, REQ'T 5, USING FIND NO 108
3. INSTALL SLEEVING OVER LEADS: FIND NO. 74 OVER C1-2, FIND NO 66 OVER C1-1.
4. STAKE WIRING USING FIND NO. 97 LEAVING NO MORE THAN 3 INCH UNSUPPORTED SPANS.
5. APPLY THIN FILM OF FIND NO. 76 TO MATING SURFACES OF FIND NOS 35 & 70
INSTALL FIND NOS 35 & 70 ON FIND NO. 2, LEAVE .06 APPROX FILLET ON FIND NO. 70 ALL AROUND.
6. ~~WIPE LIGHT COAT OF A 50-50 MIXTURE OF FIND NO. 100 AND 108~~ PER FED SPEC ~~O-A-81 IN SURFACES OF FIND NOS. 2 & 36 TO BE BOND WITH FIND NO. 78. INTERFACE OF FIND NOS. 36 & 2 TO BE FREE OF FIND NO. 78. CURE A MINIMUM OF 48 HOURS WITH AT LEAST 50% RELATIVE HUMIDITY WITHOUT APPLYING PRESSURE TO FIND NO. 36.~~
7. BOND FIND NO. 79 TO FIND NO. 2 USING FIND NO 76.
8. BOND FIND NO 40 TO FIND NO 2 (3 PLACES).
9. APPLY FIND NO. 80 TO BOTH SIDES OF UNUSED CONNECTIONS OF FIND NO. 10.
10. CENTER FIND NO. 77 WITH BOSSES OF FIND NO. 11 AND FIND NO 1 (3 PLACES).
11. PURGE AND BACKFILL WITH DRY NITROGEN USING FIND NO. 96. PRESSURE TEST AT 2-3 PSIG TO DETECT NON-LEAKAGE. APPLY FIND NO. 63 TO FIND NOS. 61 & 62 PRIOR TO INSTALLATION AFTER PURGING.
CAUTION: DO NOT EXCEED 5 PSI PRESSURE DIFFERENTIAL.
12. TORQUE FIND NO. 73 UNIFORMLY TO 4.5 ± 1 IN./LBS.
13. COAT SOLDER CONNECTIONS OF ALL RED JACKETED WIRES WITH .04-.08 INCH OF FIND NO. 98.
14. SLEEVE A2-WH WIRE .50-.75 WITH FIND NO. 103 PRIME SLEEVING .12-.38 FROM END WITH FIND NO 101 COAT A1 T1-3 AND .25-.38 OF SLEEVING WITH FIND NO. 98 APPLIED .06-.10 THICK.
15. INSTALL FIND NO 50 TO FIND NO. 30 COAT TERMINATIONS WITH FIND NO 97.
16. SLEEVE FIND NO. 14 AND FIND NO 27 WITH FIND NO 102, .50-.75 LG.
17. APPLY .06-.09 BEAD OF FIND NO. 97 OVER TERMINALS OF CR1 FOR STAKING TO FIND NO 2.
18. INSTALL R3 IN SERIES WITH U3-4 AND W2 AS SHOWN IN VIEW G-G AND STAKE USING FIND NO. 97.
19. ~~SEAT FIND NO. 105 AGAINST LENS OF FIND NO. 2 APPLY 3 SPOTS OF FIND NO. 106 TO EXTERIOR INTERFACE OF FIND NO. 106 AND FIND NO. 2.~~
20. VENDOR ITEM, SEE SPECIFICATION OR SOURCE CONTROL DRAWING.





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WIRE CONNECTION LIST

FIND NO. 30, 31 & 32 ARE HARNESSES

FROM	TO	FIND NO	REMARKS
A1-E1	S2B NO PS1-7	30	BATTERY
A1E2	PS1-6	29	FULL CHARGE
A1 E3	S3A-NO	30	BATTERY
A1E4	S1-1	30	BATTERY
A1-11	S3B-NC	A1-31	DUMP SWITCH
A1-12	L1-2	A1 35	PFN HV
A1-13	S3B-C	A1 31	DUMP SWITCH RTN
A1 14	E1	A1-34	HV RTN
A1-15	PS1-9	A1 31	PFN HV
A2 RED	L1-1	A2-5	FLASHLAMP HV
A2 BLK	E1	A2 5	FLASHLAMP HV RTN
A2 WHT	A1T1-3	A2-4	FLASHLAMP TRIGGER
C1-1	E1	C1	HV RTN
C1-2	L1 2	C1	PFN HV
CR1 1	PS1-2 U3-10	32	+12VDC
CR1-3	U3-9	32	START
CR2-A	E1	E1	HV RTN
CR2-C	L1-2	67	PFN HV
DS1-1	S5-NO	32	BATTERY
DS1-2	R2-3	32	RETICLE POT
E1	PS1-1	68	CHASSIS GND
E[illegible]	S1 C	30	BATTERY
PS1-3	U3-11	32	+12 VDC RTN
PS1-4	U3-12	32	4 VDC
PS1-5	S2A-NO S4A-NO U3-13	30	BATTERY

FIND NOS. 30 31 & 32 ARE HARNESSES

FROM	TO	FIND NO.	REMARKS
PS1-10	U2-7	31	AGC VOLTS
PS1-11	U2-6	31	-12VDC (VIDEO AMP)
PS1-12	U1-7	31	-12VDC (PRE-AMP)
PS1-14	U1-11	31	DET HV
PS1-15	U1-12 U2-3	31	+ 12 VDC
R1-1	U3-1	30	MIN RNG POT RTN
R2-1	R2-2 E1	30	CHASSIS GND
R3	PS1-6	30	FULL CHARGE
S2A-C	S2B-C S3A C S4A-C S5-C	30	BATTERY
S4A-NC	S4B-C	30	BATTERY
S4B-NO	U3-3	30	MIN RNG SW
U1-2	E3,E4 PS1-13 U1-9 U2-4	31	RTN
U1-5	U2-5	31	PREAMP OUTPUT
U2-1	P4	30	STOP
U2 2	U3-5	30	TPG GATE
U3-4	P4		STOP
U3-7	R3	30	FULL CHARGE
U3-2	R1-2 R1-3	30 30	MIN RNG POT

FOR PARTS LIST SEE PL-SM-B-852005

RCA Burlington Mass

U S ARMY ELECTRONICS COMMAND
PROCUREMENT AND PRODUCTION DIRECTORATE
FORT MONMOUTH NEW JERSEY 07703

RANGEFINDER, LASER
AN/GVS-5 ( ) ASSEMBLY

E 80063 SM-E-852005

SHEET 1 OF 3

WHEN REFERRING TO THIS DRAWING STATE DRAWING NO., APPLICABLE ISSUE LETTER IF ANY, AND DATE

Figure 2-1. HHLR Configuration
(Sheet 1 of 3)

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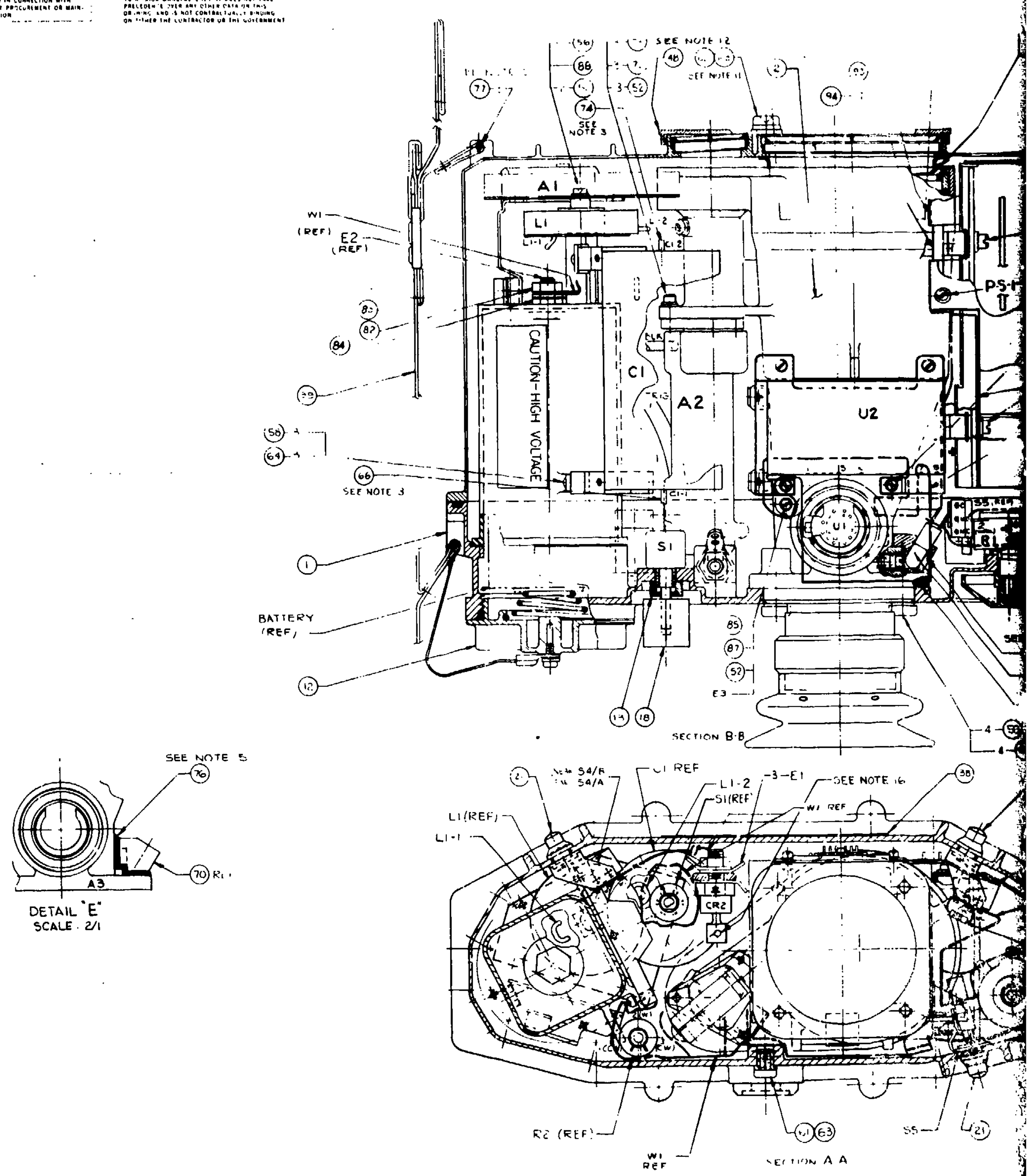

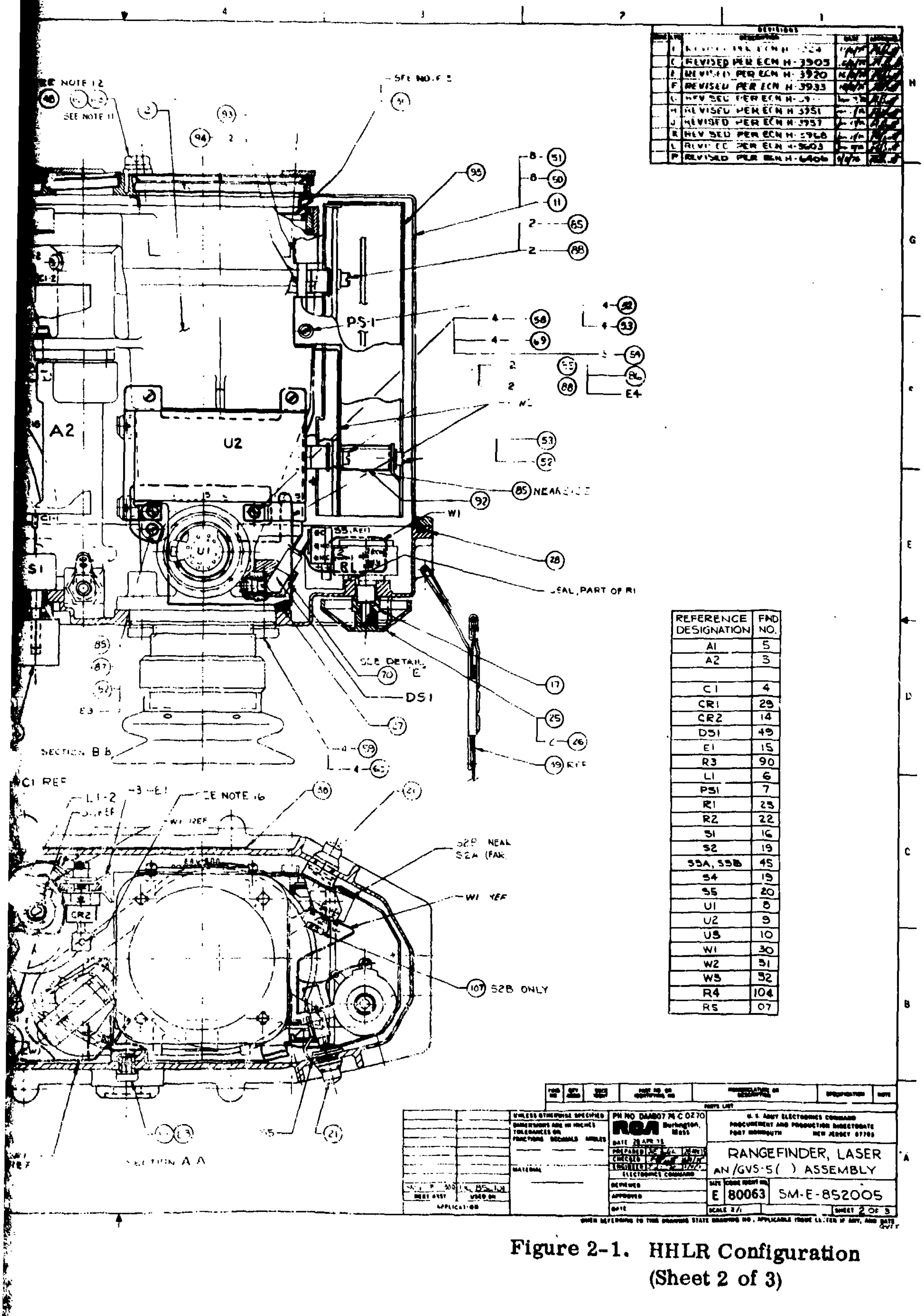

REFERENCE DESIGNATION	FND NO.
A1	5
A2	3
C1	4
CR1	29
CR2	14
DS1	49
E1	15
R3	90
L1	6
PS1	7
R1	23
R2	22
S1	16
S2	19
S3A, S3B	45
S4	19
S5	20
U1	8
U2	9
U3	10
W1	30
W2	31
W3	32
R4	104
R5	07

Figure 2-1. HHLR Configuration
(Sheet 2 of 3)

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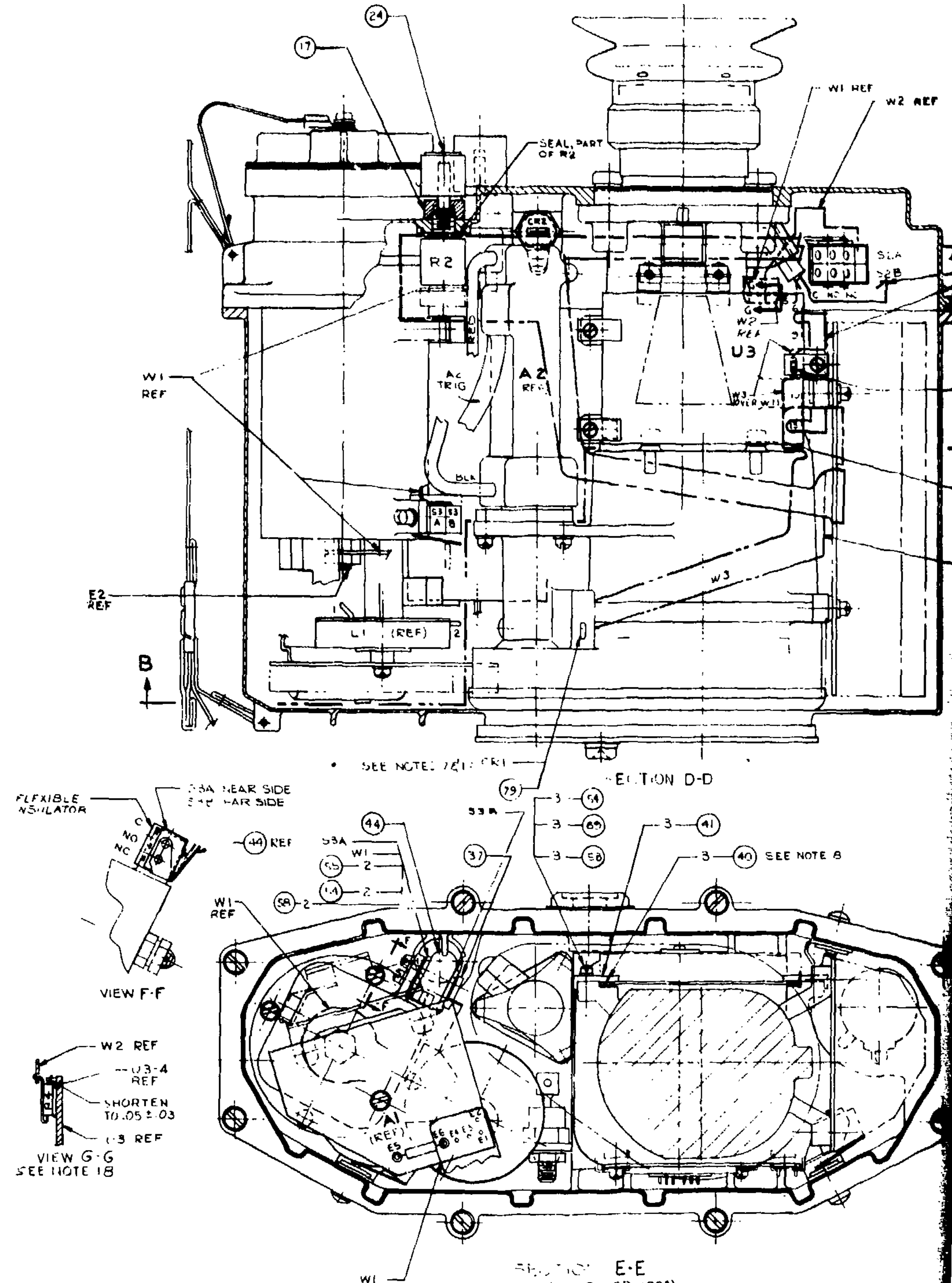

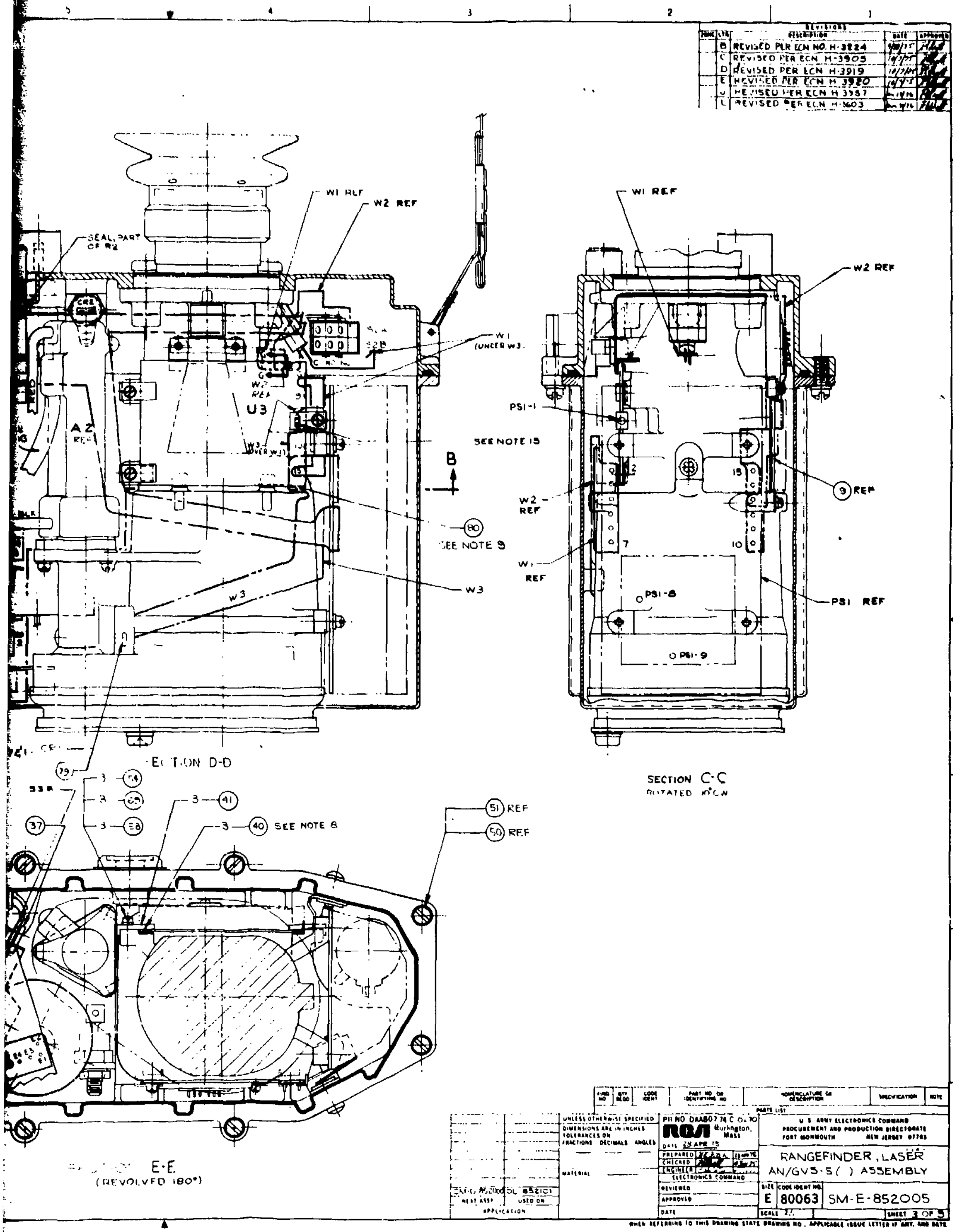

Figure 2-1. HHLR Configuration
(Sheet 3 of 3)

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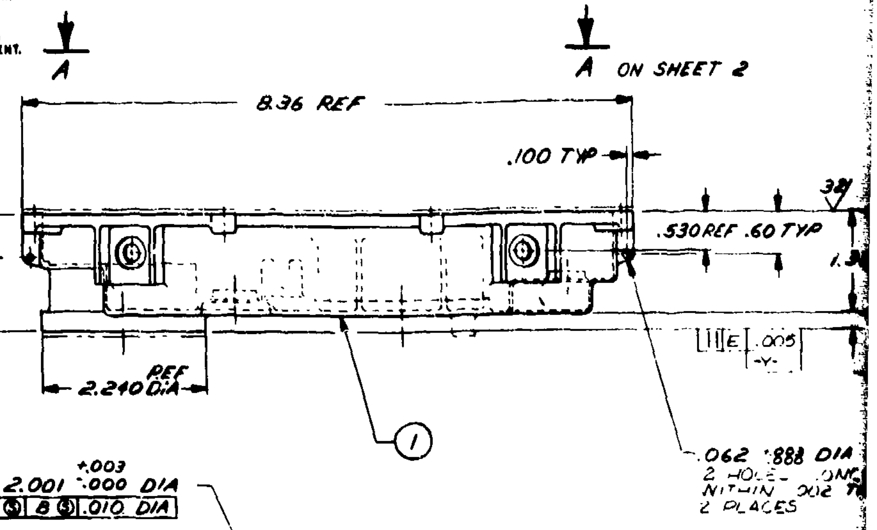
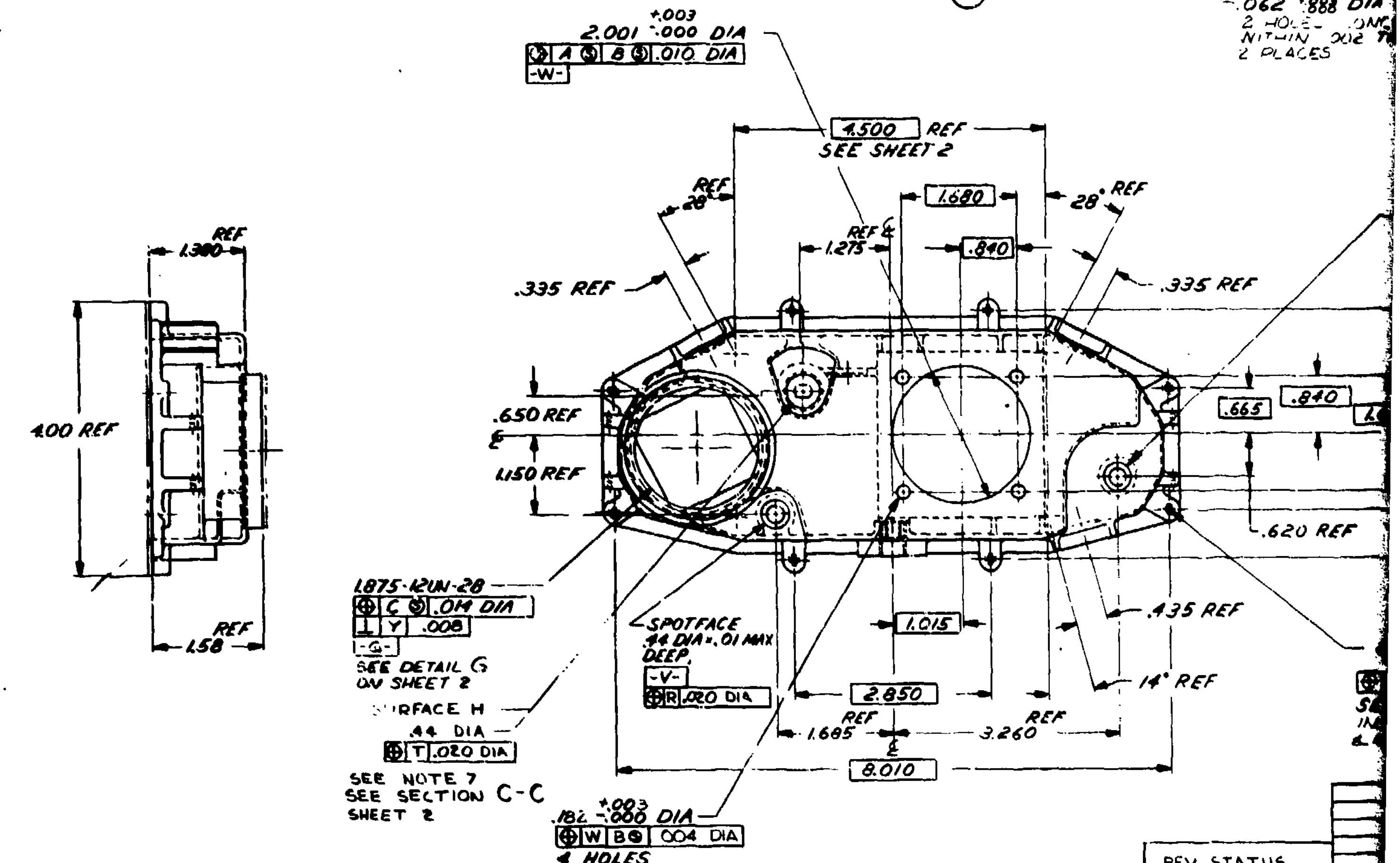
NOTES:
1. WORKMANSHIP SHALL BE IN ACCORDANCE WITH MIL-STD-454, REQT 9.
2. UNLESS OTHERWISE SPECIFIED ALL MACHINED SURFACES SHALL NOT EXCEED ✓ PER USASB46.1-1962
3. DIMENSIONS AND TOLERANCES PER ANSI Y14.5-73.
4. INSTALL FIND NO.2 PER MS33537 PRIOR TO PAINTING PER NOTE 7.
5. IMPREGNATE PER MIL-STD-276 TO MEET A 15 PSIG PROOF PRESSURE.
6. PLATING: PRETREAT WITH SODIUM ZINCATE, OR EQUAL. COPPER PLATE PER MIL-C-14550, CLASS 3, AND ELECTROLESS NICKEL PER MIL-C-26074, CLASS 4, GRADE B. FINAL PLATING HARDNESS TO BE R 40-50.
7. PAINTING: PRETREAT, PRIME, AND PAINT ALL OUTSIDE SURFACES EXCEPT E,H,J,K,L,M,N,P,R,V,W,Y & Z THREADS, & THROUGH HOLES. AFTER CLEANING, APPLY PRETREATMENT COATING, 0.5 TO 0.7 MIL (DRY FILM) THK, PER MIL-P-15328. PRIME AND PAINT USING MIL-P-23377 AND SM-A-852286 APPLIED PER MIL-C-81773.
8. IDENTIFY PER MIL-STD-130.
9. THREAD DATA PER NBS HANDBOOK H28.





REV STATUS

SH	REV	SH	REV
1	G		
2	G		

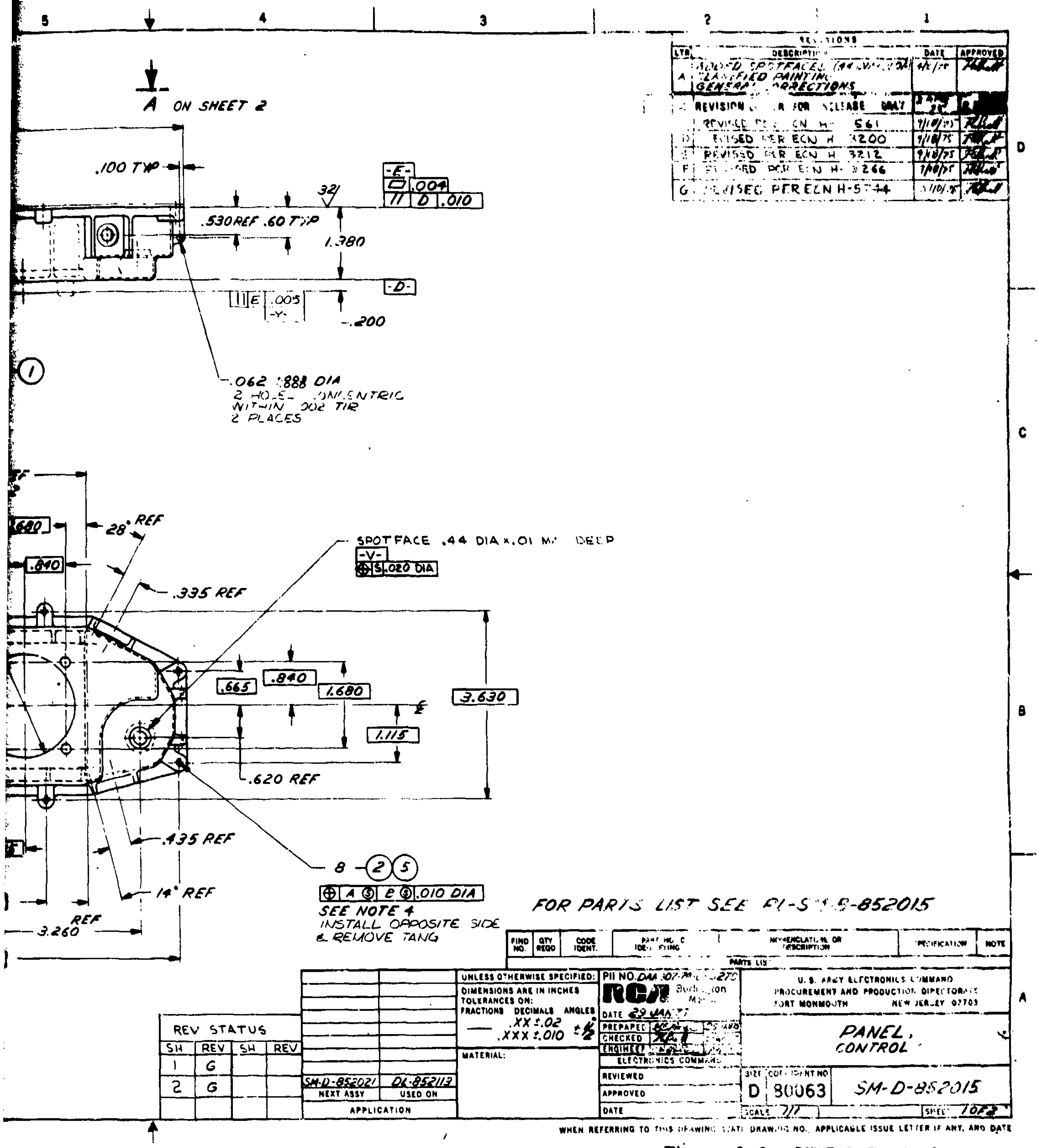


Figure 2-2. HHTR Control Panel
(Sheet 1 of 2)

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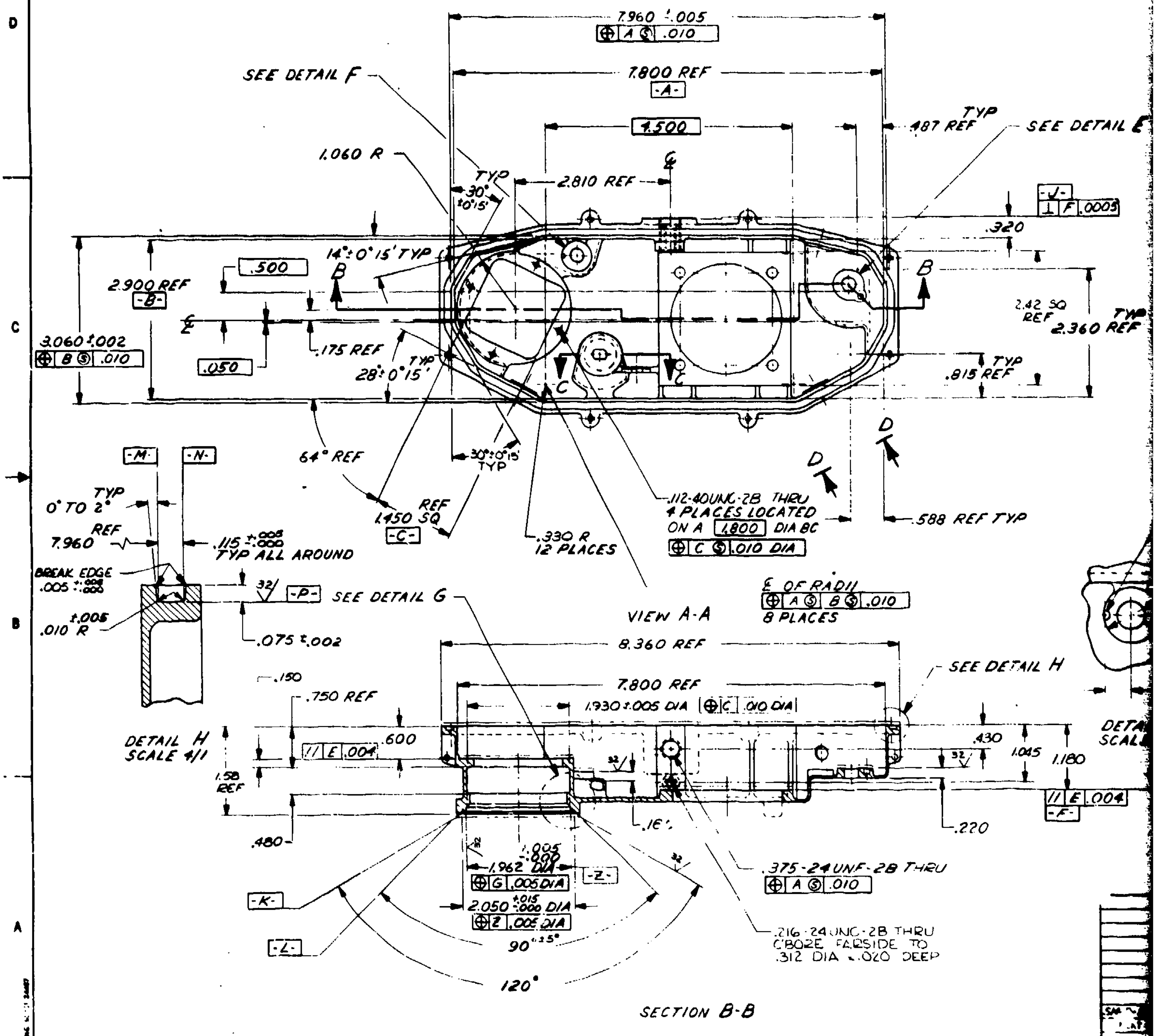

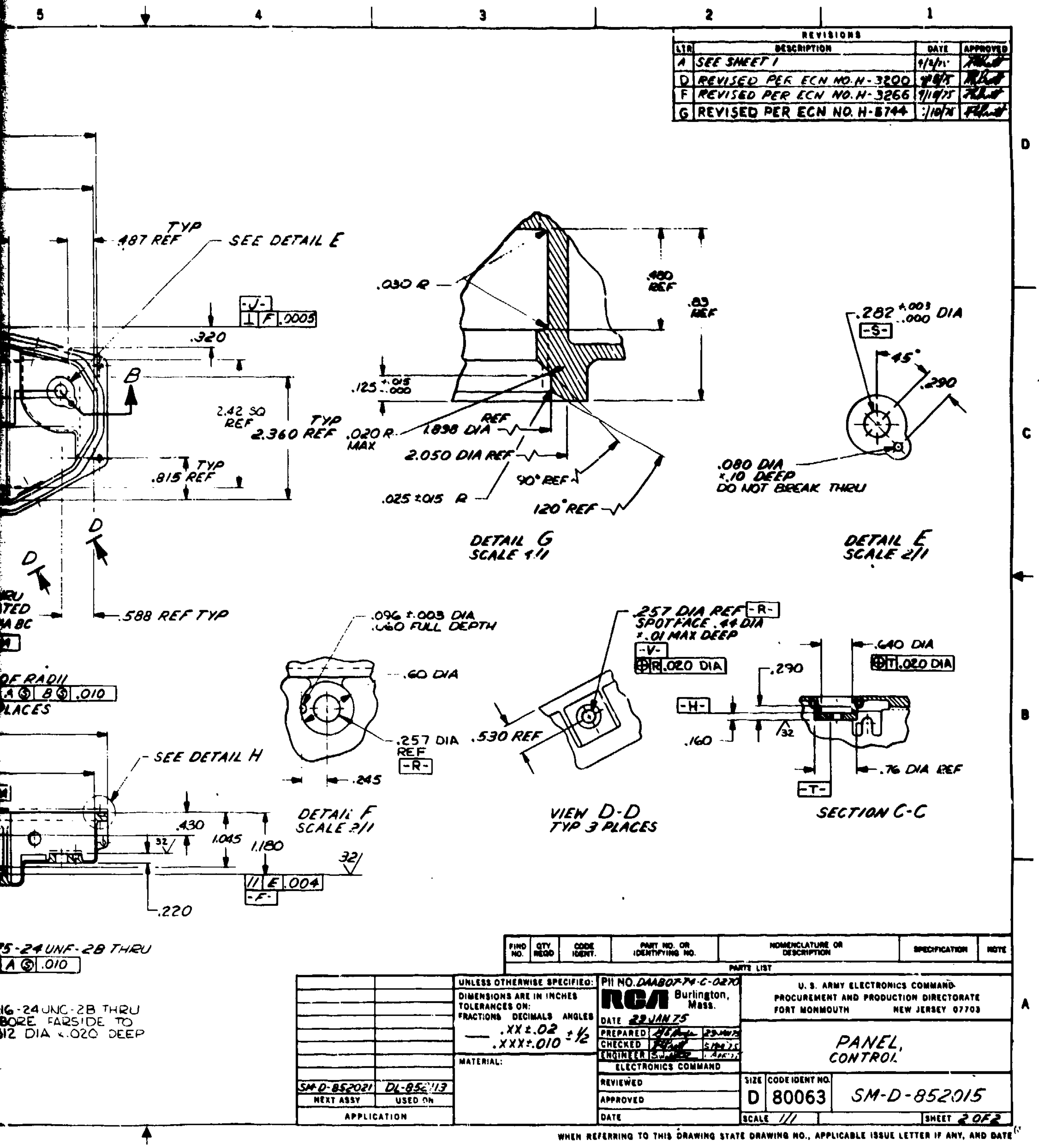

Figure 2-2. HHLR Control Panel
(Sheet 2 of 2)

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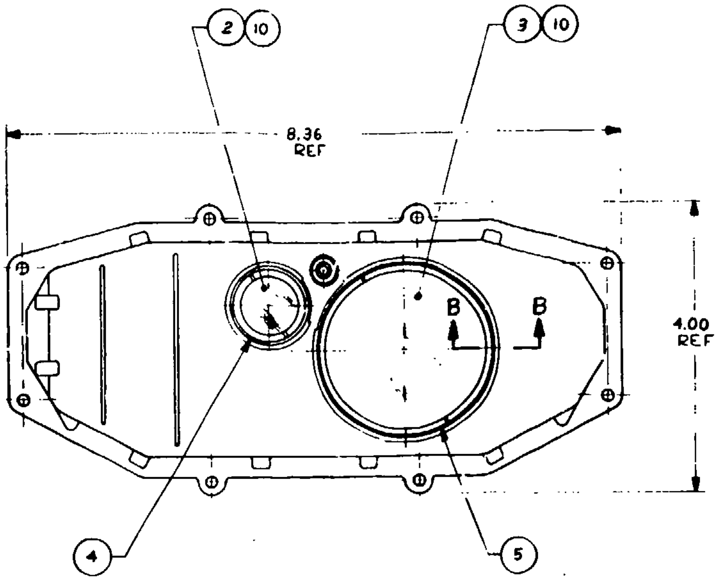
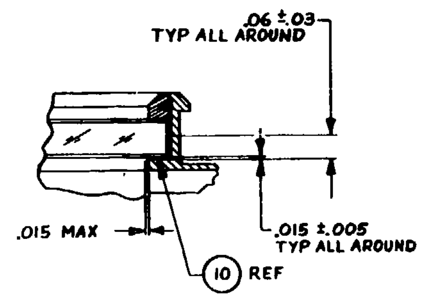
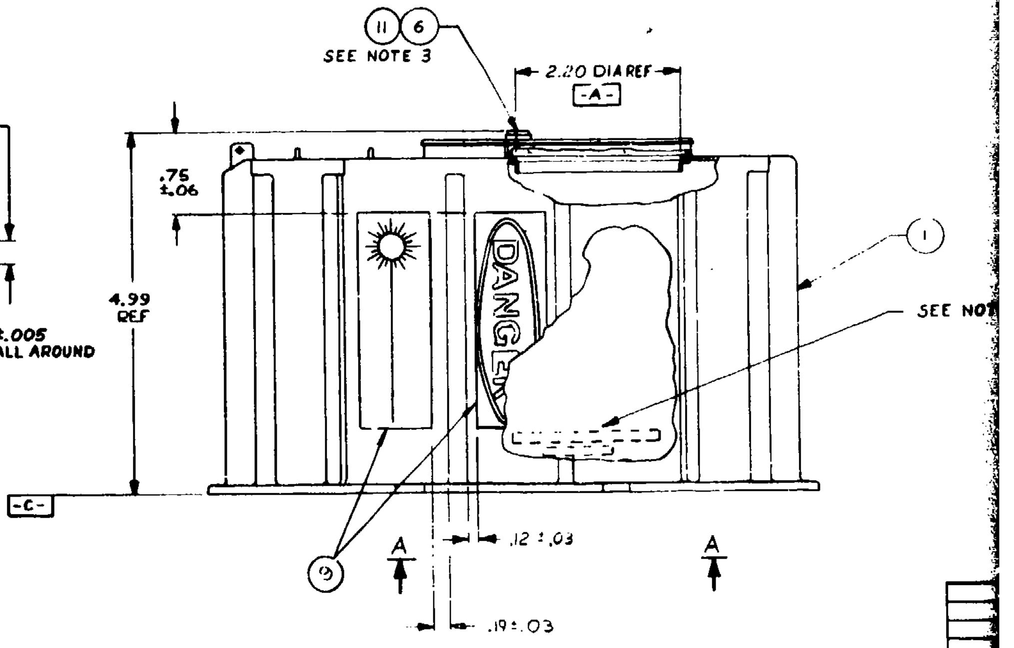
NOTES:
1. WORKMANSHIP SHALL BE IN ACCORDANCE WITH REQUIREMENT 9 OF MIL-STD-454.
2. BOND FIND NO. 7 TO FIND NO. 1 USING FIND NO. 10.
3. PRIME WITH FIND NO. 13, DRY AND COAT WITH FIND NO. 11 THREADS OF FIND NO. 6 PRIOR TO ASSEMBLY.
4. MARK AS SHOWN WITH .12 HIGH STANDARD GOTHIC CHARACTERS USING BLACK INK FIND NO. 12, PER MIL 14-12221 PER MIL-STD-130. LOCATE APPROX. AS SHOWN, THE FOLLOWING INFORMATION: 80063 ASSY 852012
MFG. [-----]
INSERT CURRENT MANUFACTURES CODE IDENT NO.
5. WITH SURFACE "C" AND FIND NO. 6 SEALED THE ASSEMBLY SHALL WITHSTAND AN INTERNAL PRESSURE OF 8 PSIG WITH NO LEAKAGE.
6. VENDOR ITEM SEE, SPECIFICATION OR SOURCE CONTROL DRAWING.





SECTION B-B
FIND NO. 7 NOT SHOWN
SCALE NONE
TYP 2 PLACES



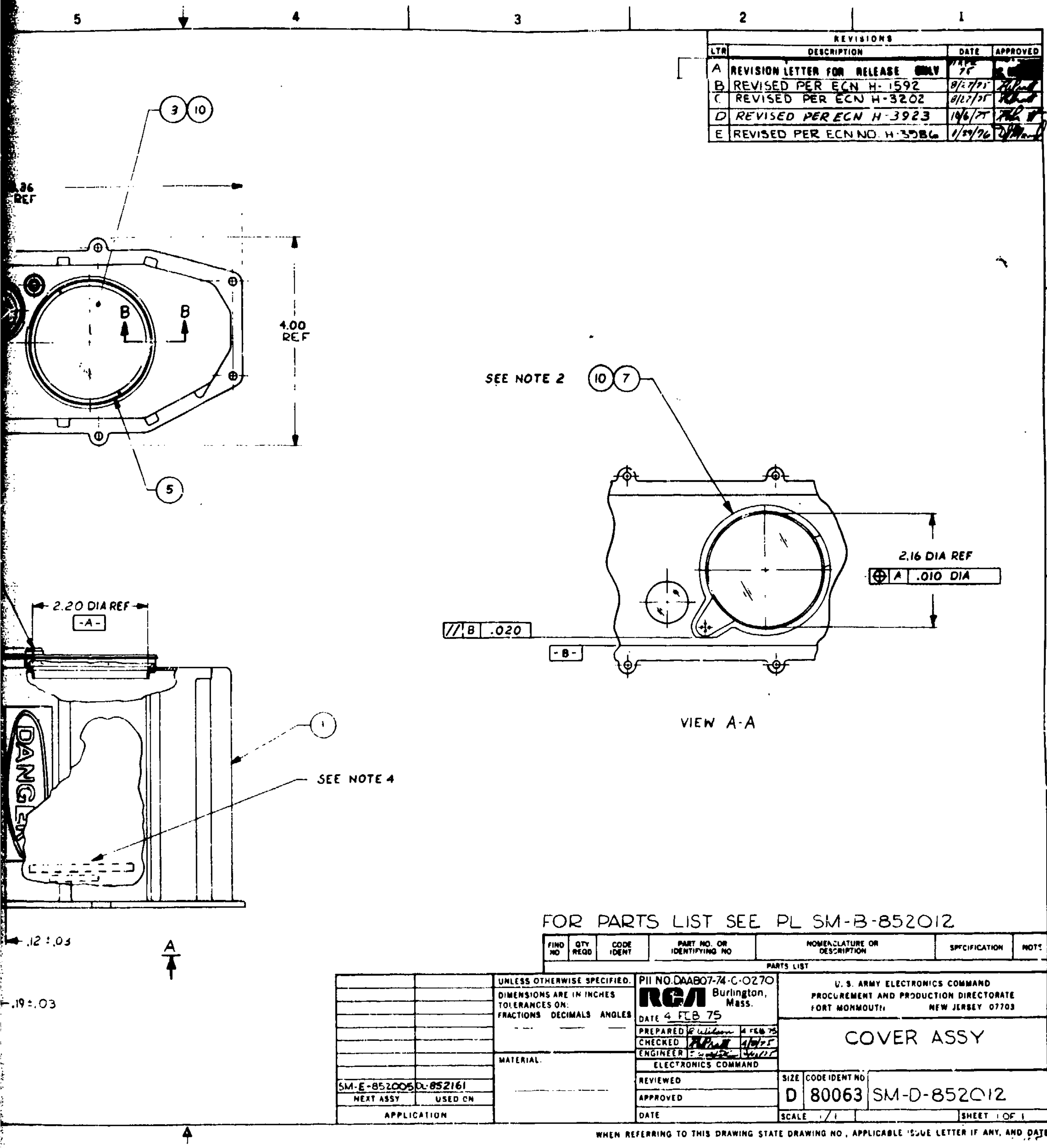


Figure 2-3. HHLR Cover Assembly

The Optical Assembly, which mounts to the Control Panel by four screws, supports the Detector-Preamplifier, Video Amplifier, Range Counter, Power Supply, and Laser Transmitter Module.

Control switches and pots and the Pulse Forming Network (PFN) diode are mounted on the Control Panel directly.

The Battery Container which is fastened to the Control Panel by four screws and bonded to provide a watertight seal, supports the remaining electronics.

The electronic packaging as described in the Design Plan, paragraph 2.1.1 pp 2-13, 2-14 has been changed only to the extent discussed below:

The battery container, of injection molded polycarbonate, has been configured to also serve as the structure which mounts the pulse forming network (except for the diode), the trigger circuit assembly, and the two safety interlock switches. The switches mount directly to a post on the battery container; the PFN inductor and the printed circuit board of the trigger circuit assembly share a common mounting post at the end of the battery container. The trigger transformer and a physically large capacitor are located on a sheet-metal mounting bracket. This bracket serves double-duty in that it is also used to structurally tie the edge of the trigger circuit board to the side of the battery container. The pulse forming network capacitor is mounted along a side of the battery container by means of molded polycarbonate feet which are bonded to the ends of the capacitor and fastened to the battery container.

The conformal coating used on the trigger circuit assembly is colored red as an additional warning of the presence of high voltage to the operator, when the cover is off.

A two-part aluminum cover has been added over the Power Supply for proper shielding. This cover has a red conformal coating to provide electrical insulation and to warn the operator of the presence of high voltage.

Except for the hard wires used in the PFN and Trigger circuit loop, the flash lamp interconnections, and the chassis ground connection from the Power Supply, all electrical interconnections are made by flexible printed wiring.

2.1.1.3 Environmental Protection

In the Design Plan, paragraph 2.1.3 pp 2-15 thru 2-18, there is a discussion of the possible need for use of a conductive elastomer for the cover-to-control-panel seal and for conductive rotary shaft seals to maintain EMI integrity. The

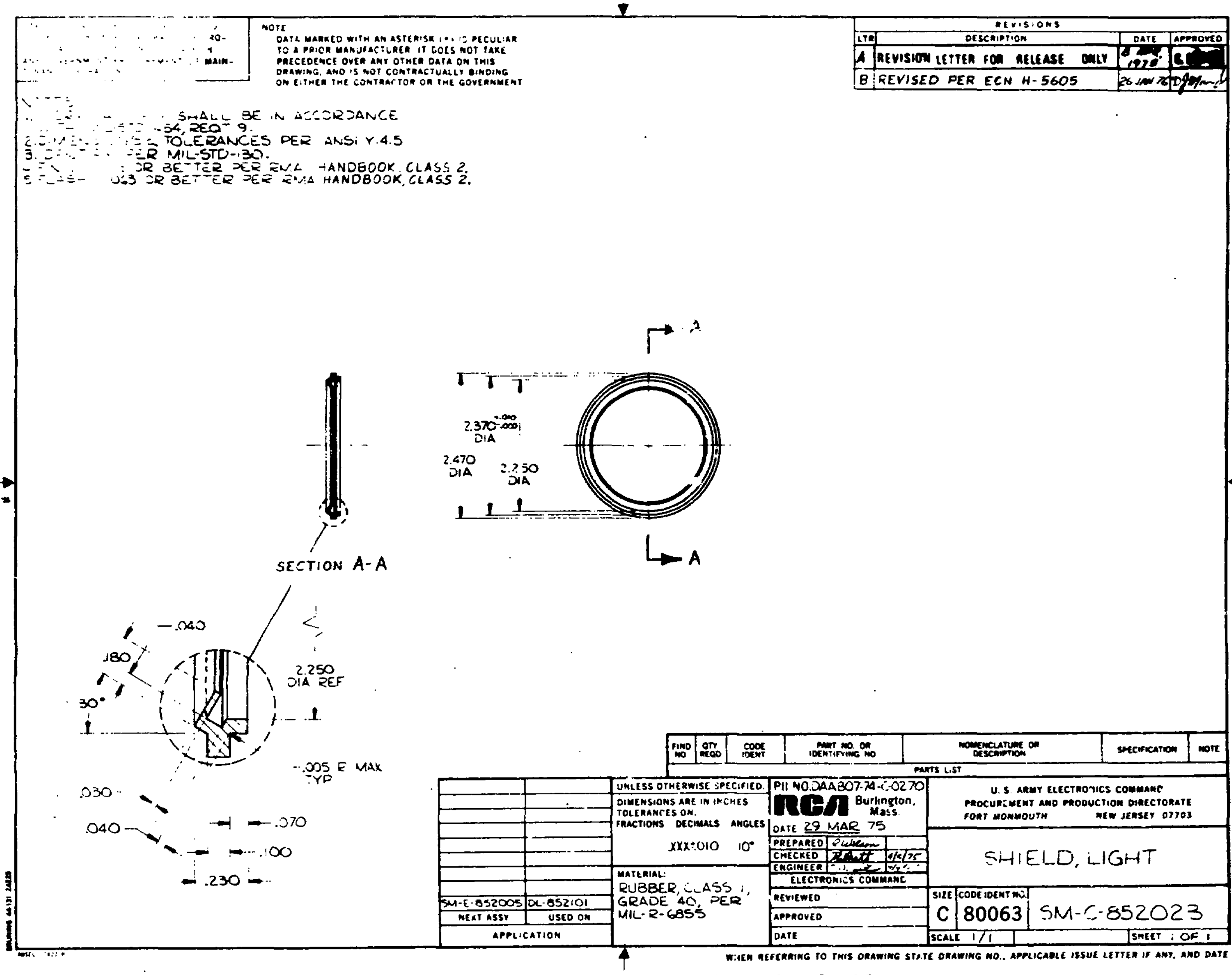


Figure 2-4. Optical Assembly Light Shield

final design has not required either of these. Instead, a non-conductive silicone elastomer housing seal and standard non-conductive rotary shaft seals are used. EMI integrity has been maintained by the metal-to-metal contact provided by the mating surfaces of the housing and by the metal-to-metal contact within the shaft assemblies, as discussed in the Design Plan.

Initially it had been intended to provide a single purge port in the cover for purging the HHLR with dry nitrogen. The process to be used required removal of the purge screw, placing the HHLR in a vacuum chamber, slowly pulling a vacuum, and then back filling with dry nitrogen. By this approach, there would be no pressure differential across the cover and thus no concern about overstressing the cover. However, this approach is a bit complex and would require vacuum equipment in the field for maintenance operations.

The design has been changed to incorporate an additional purge screw in the control panel. This permits a simpler procedure which requires only that dry nitrogen be forced through the HHLR at low pressure (2 to 3 PSI) for 30 minutes after which the purge screws are replaced. With this technique the HHLR is purged and filled with dry nitrogen, but is not pressurized.

2.1.2 Optical Assembly

2.1.2.1 External Configuration

The HHLR Optical Assembly consists of two telescopes in one common aluminum casting: (1) a transmitter telescope to steer the laser beam and reduce its angular beam divergence, and (2) a coaxial sighting and receiving telescope to sight on the desired target and receive the reflected laser energy.

The Optical Assembly is a major structural support and mount for the laser transmitter module, the power supply module, the detector/preamplifier module, the video amplifier, and the range counter/display assembly. These subassemblies mount to cast bosses in the telescope housing.

The transmitter and sighting/receiving telescope barrels, although part of the same casting, are optically isolated from one another by a structural wall to prevent strong laser light from getting to the sensitive detector. Each telescope is purged and sealed independently for this reason.

Figure 2-5 shows the envelope of the final configuration of the Optical Assembly.

2.1.2.2 Sighting/Receiving Telescope

The description of the Sighting/Receiving Telescope is unchanged from that written in Para. 2.2.2 pp 2-25 thru 2-27 of the Design Plan except in the next to the last paragraph. The 0.003 inch shift of the field stop image on the detector active area due to temperature variation does not actually exist. The shift of elements occurs in the collimated light path between the narrow bandpass filter and the focusing lens. The clear aperture of the focusing lens is appreciably larger (0.110 inch dia.) than the projected diameter from the filter (0.056 inch diameter). The two focii can, therefore, be 0.034 eccentric without loss of energy due to vignetting.

2.1.2.3 Display Optics, Reticle, and Illumination

The optical and constructional details of this section are correct as written in Para. 2.2.3 pp 2-28 & 2-29 of the Design Plan with the following change. The 10,648Å filter window referenced in the last paragraph was eliminated to improve the illumination level on the reticle. The fear that 10,648Å energy from the reticle light might reduce receiver sensitivity proved unwarranted and the filter removed too much useful light. The red filter element was retained but the 10,648Å filter was replaced with a clear, prismatic element to provide more uniform illumination.

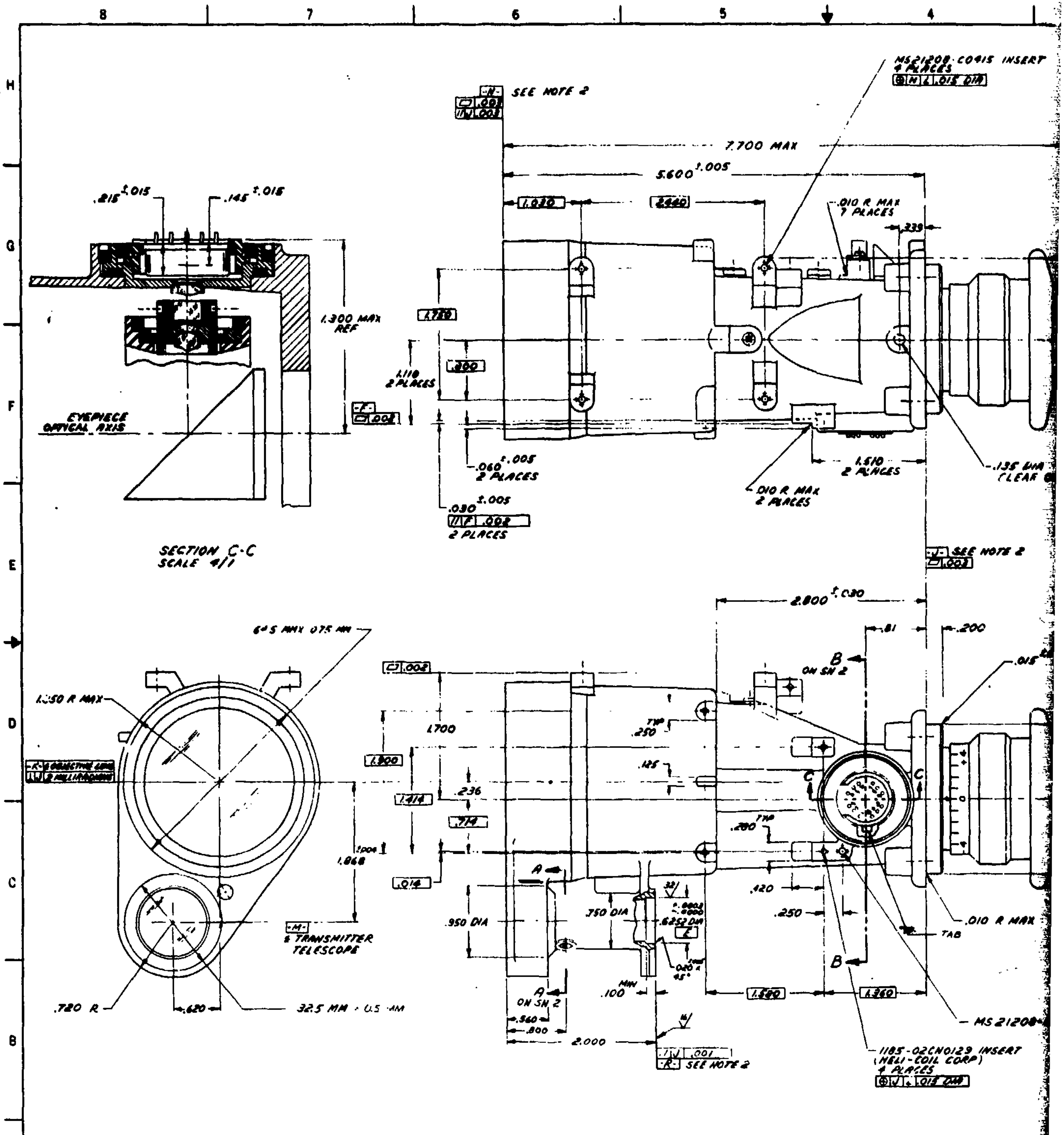
2.1.2.4 Transmitter Telescope

The transmitter telescope is a four power Gallilean, as described in the design plan, but with a lengthened purge screw to scatter energy into the start pulse diode. This change, contemplated as a contingency if the scattered, off-axis energy was insufficient to provide an adequate start pulse, was found necessary in some units, so was implemented in all for standardization.

2.1.2.5 Boresight Alignment

Problems experienced with boresight shifts in some of the rangefinder units were traced to incompletely cured adhesives. Increasing curing times and temperatures stabilized the adhesive joints, thus minimizing boresight changes as a function of time and temperature.

The material used to bond the prism cluster to its metallic support was changed from EC801, a flexibilized polysulfide, to a structural epoxy per MMM-A-131. EC801 is retained for bonding the field stop support saddle to the beam splitter prism. The cure temperature of the latter bond was increased to 180°F to



NOTES:
1. FOR SPECIFICATION SEE DWG 2375195
2. SURFACES -J-, -N-, -R- AND -S- TO HAVE LOW ELECTRICAL RESISTANCE FINISH PER MIL-C-5541B, CLASS 3. REMAINDER OF SURFACES TO BE DULL BLACK ANODIZE PER MIL-A-8625, TYPE II, CLASS 2

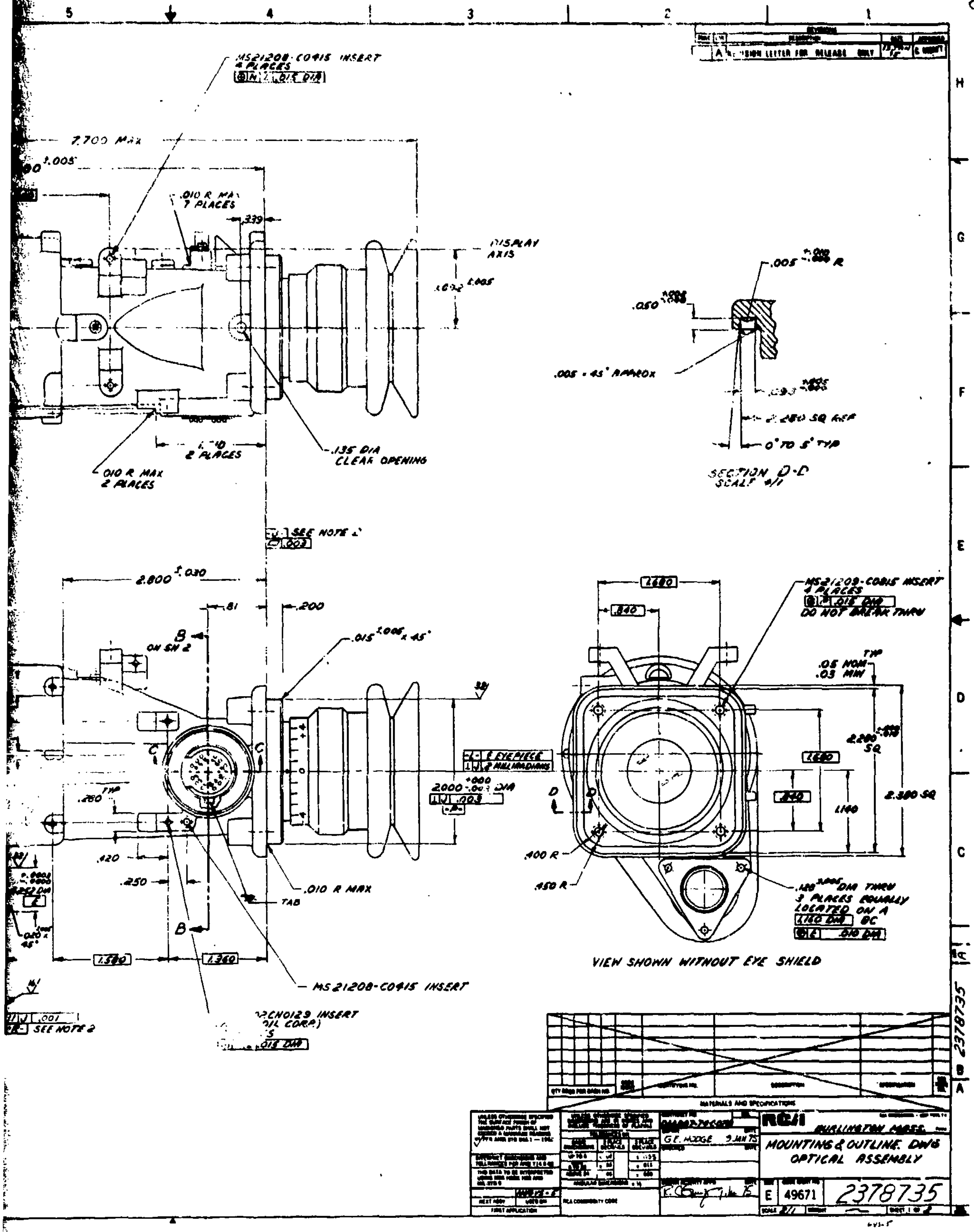
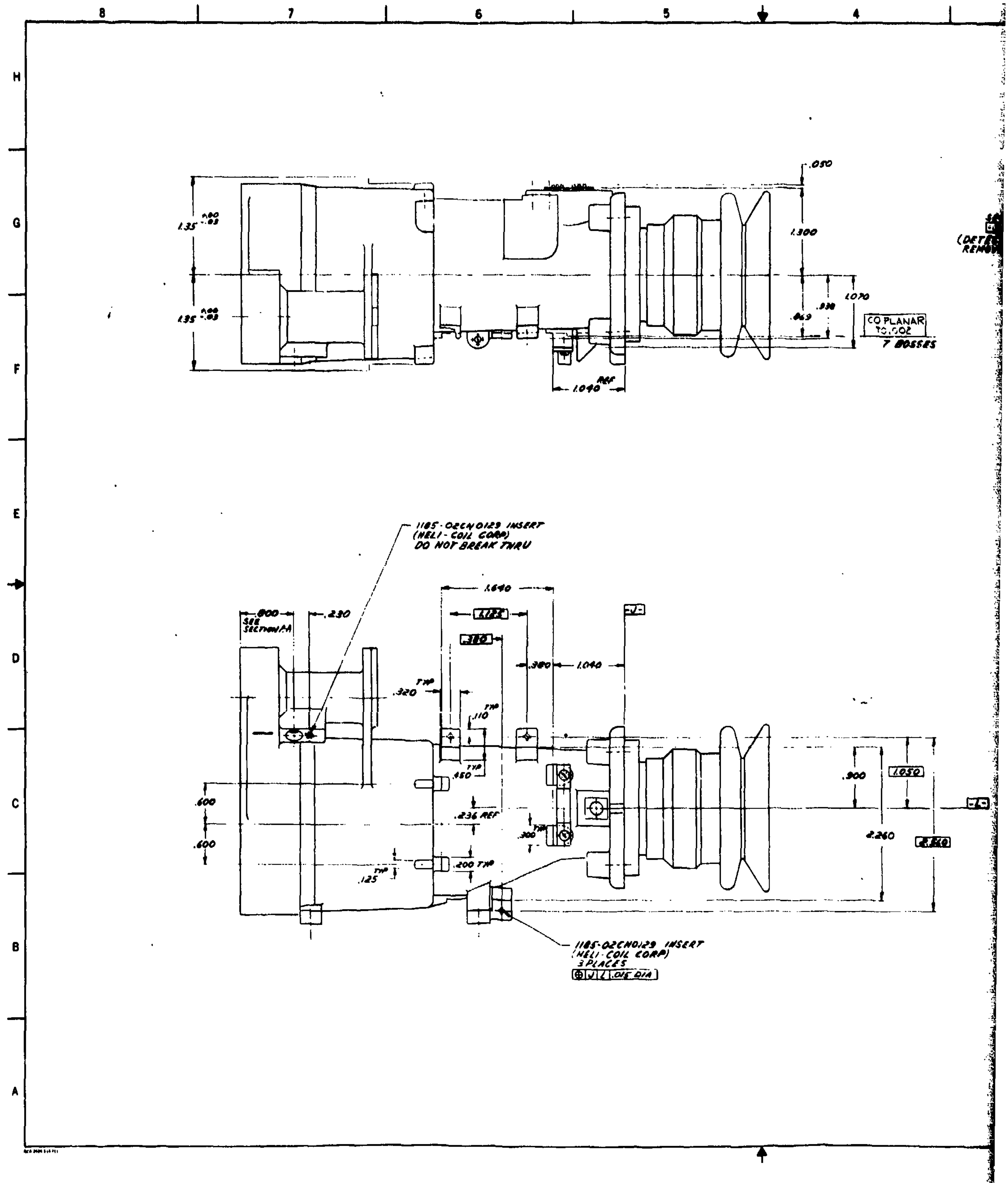


Figure 2-5. Optical Assembly Outline Drawing (Sheet 1 of 2)



1185-02CN0129 INSERT
(HELI-COIL CORP)
DO NOT BREAK THRU
1185-02CN0129 INSERT
(HELI-COIL CORP)
3 PLACES
CO PLANAR
TO .002
7 BOSSES
SEE SECTION A-A
1.640
1.040
.050
1.300
1.070
2.260
.900
1.050
.600
.320
.110
.230
.800
.380
.236 REF
.200 TYP
.125
1.040 REF

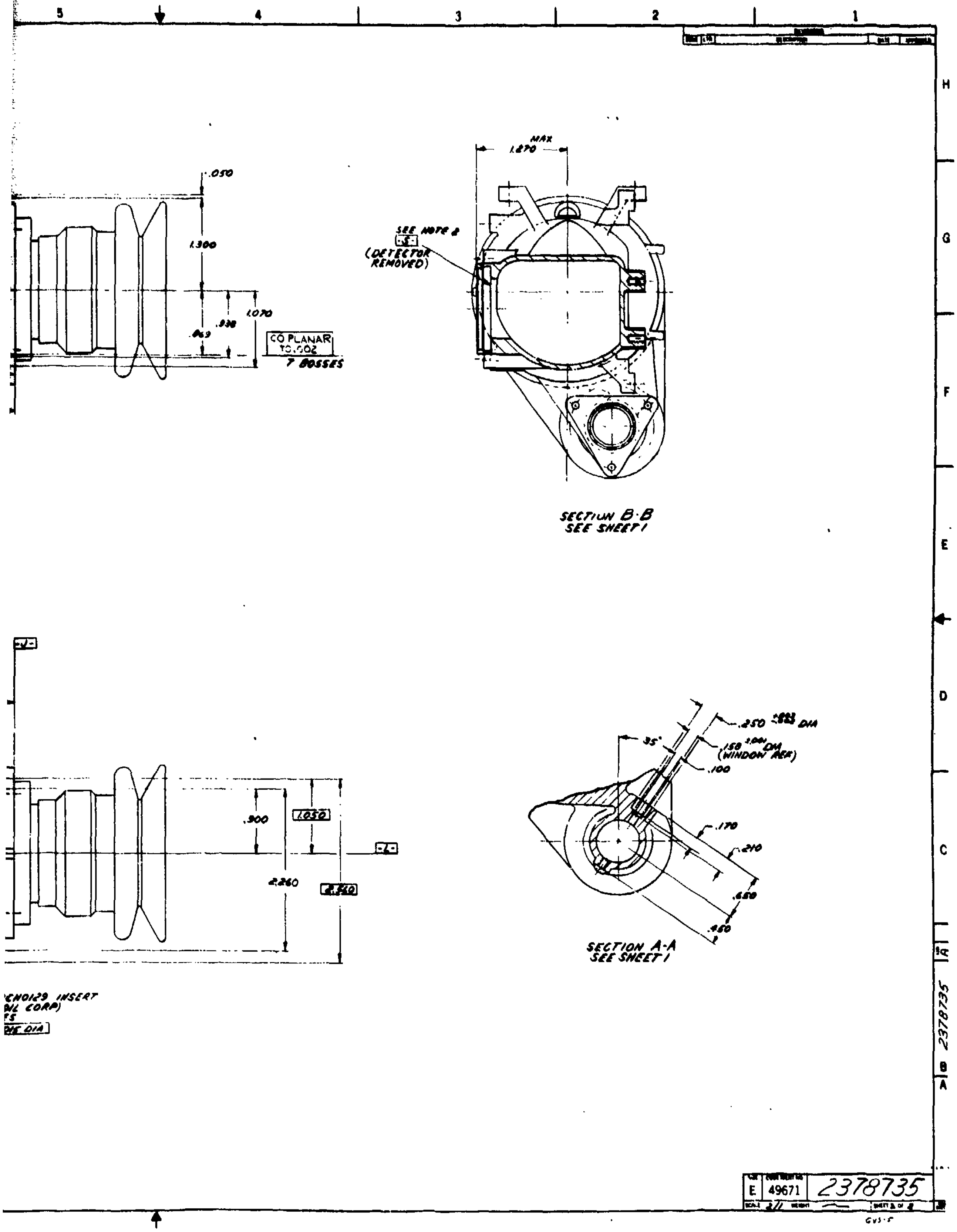


Figure 2-5. Optical Assembly Outline Drawing (Sheet 2 of 2)

conform to other cycles and eliminate a change in receiver-sight alignment experienced in some of the optical systems after alignment and final test by the vendor.

2.1.3 Laser Transmitter

2.1.3.1 Configuration

The final design of the Laser Transmitter Module was accomplished at RCA after submission of the Design Plan. This resulted from a decision to transfer the transmitter from IBM Federal Systems Division to RCA. This design is represented by Figure 2-6.

The Laser Transmitter Module (LTM) is configured to be cantilever-mounted from the transmitter telescope. The perpendicularity and concentricity alignment of the resonator axis to the mounting flange is critical to allow LTM interchangeability without requiring reboresighting the system. For this reason the resonator is integral to the mounting flange. The two piece plastic cavity housing is also cantilevered from the flange and contains the remainder of the LTM components: the UV blocking filter, the flashlamp, and trigger wire. The LTM subassemblies and components are described in more detail in the following paragraphs. The entire LTM assembly weighs 0.1 pound.

2.1.3.1.1 Resonator Subassembly

The resonator subassembly consists of the mounting flange, the laser rod, and a metal ferrule containing the Q-switch, rear mirror, and double wedge alignment mechanism. The optical resonator is the axial portion between the front (flange) surface of the laser rod and the reflective surface of the rear mirror; this length is nominally 1.95 inches.

The laser rod is neodymium doped synthetic yttrium aluminum garnet (Nd:YAG) 4.27 mm diameter by 43 mm long. The rod ends are flat to $\lambda/10$, parallel to 10 arc seconds and perpendicular to the cylinder axis to 5 arc minutes. The output end of the rod (mounting flange end) is dielectric coated for 60% reflectivity at the laser wavelength. The other end is anti-reflection coated for maximum transmission. The laser rod ends - less chamfers - provide a 4.0 mm minimum clear aperture.

The Q-switch is cellulose acetate containing the bleachable dye with an unbleached density of 0.38 at 1.06 microns. The rear mirror is a first surface reflector with multilayer dielectric high reflectivity coatings ($\rho \cong$ 100%) at

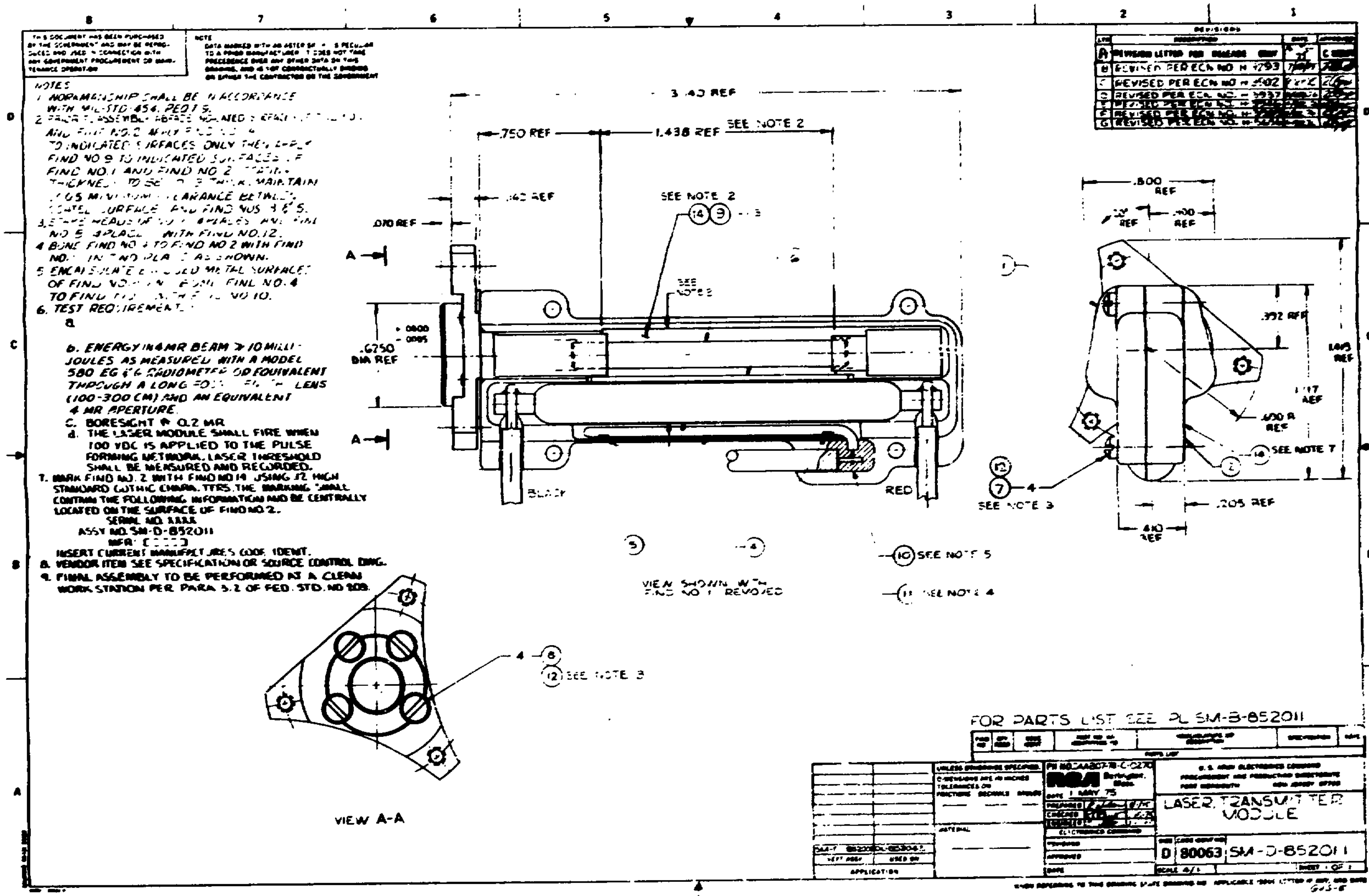


Figure 2-6. Laser Transmitter Module

. .. microns. The rear end of the laser rod, Q-switch surfaces and mirror reflector surface are sealed within the ferrule housing to provide protection against environmental damage.

The laser rod front surface is optically aligned to the front surface of the mounting flange, then the rod is epoxy bonded into the flange. After curing of the flange-rod joint the ferrule is similarly aligned and bonded to the rear end of the laser rod.

Final assembly consists of installing the Q switch in its support, the O ring, mirror and wedges, then the retainer screw cap in the ferrule. The reflecting surface of the rear mirror is then optically aligned parallel to the rod front face to complete the resonator.

2.1.3.1.2 Module Assembly

The main housing for the LTM consists of two molded, polycarbonate shells. Their parting surface lies along the plane of symmetry to facilitate assembly and fabrication. The halves, clamped together with four screws, pilot to the resonator for precise location and attach to the flange with four screws. The housing supports the UV filter between the flash lamp and laser rod, the flash lamp, and lamp trigger wire. The housing also forms the reflective pump cavity. The diffuse reflector surface is a sprayed on, white, emulsion.

The flash lamp has solder leads attached to the electrodes and is mounted in the cavity with the anode end away from the flange to prevent high voltage arcing. The lamp is 5 mm diameter by 70 mm long; the bore is 3 mm and the arc length is 35.5 mm nominal. The lamp is Xenon filled to a pressure of 600 Torr.

The tinned copper trigger wire is housed in a quartz capillary tube and is cut and formed to the proper form factor. This assembly is mounted along the length of the flash lamp just beneath the cavity reflector coating.

2.1.3.1.3 Structural/Mechanical Considerations

The design analysis for the earlier configuration, Para. 2.3.4 pp 2-65 & 2-66 of the Design Plan remains essentially the same. Although assembly differences exist in the ferrule components, the weight change and mechanical impact are slight. Shock tests on the resonator were satisfactory to 500g, 1.5 ms but produced a failure at the 600g, 1.0 ms level. These levels are far above the AN/GVS-5 spec. requirement.

2.1.3.2 Laser Performance Characteristics

The performance characteristics were measured on the twenty laser transmitter modules that were installed and delivered in the HHLRs. Each unit was tested for laser output, beam divergence, single and double pulse threshold, and pulse width. (The flange-to-resonator boresight of the module is established at the fabrication level to the required 0.3 mr.)

2.1.3.3 Test Data

The Laser Transmitter module is tested several times before installation in a rangefinder. The resonator assembly is dynamically tested in a test cavity during the alignment cycle. The beam divergence measurement is used as a check of resonator alignment. The resonator is then pumped down in a vacuum and back filled with nitrogen and sealed. After sealing it is again tested in a test cavity before being incorporated into the final Laser Transmitter Module assembly. After assembly, final LTM testing is completed and data is recorded. The following is a summary of the LTM final test data:

Laser Output

Energy in full beam

HIGH - 16.8 millijoules
LOW - 11.7 millijoules
AVERAGE - 13.2 millijoules

Energy in 4 milliradian beam

HIGH - 15.6
LOW - 10.0
AVERAGE - 12.1

Beam Divergence (% energy in 4 mr.)

HIGH - 99%
LOW - 76%
AVERAGE - 92%

Laser Output (Continued)

Pulse Width (@ half Amplitude)

HIGH - 7 nanoseconds
LOW - 6 nanoseconds
AVERAGE - 6.5 nanoseconds

Boresight of L.T.M. to reference mount

HIGH - 60 arc seconds
LOW - 10 arc seconds
AVERAGE - 36 arc seconds

Single Pulse Threshold

HIGH - 710 volts (6.7 joules)
LOW - 620 volts (5.1 joules)
AVERAGE - 680 volts (6.1 joules)

Double Pulse Threshold

HIGH - 890 volts (10.5 joules)
LOW - 790 volts (8.3 joules)
AVERAGE - 830 volts (9.1 joules)

Two Laser Transmitter Modules were life tested at 50°C at a repetition rate of ten pulses per minute. Life test results are reported in the Reliability Test Final Report (CDRL Sequence No. G003). End point data is as follows:

	LTM No. 3982 Start	LTM No. 3982 End	LTM No. 3983 Start	LTM No. 3983 End
Energy in 4 milliradian beam (mj)	14.5	6.8	10.1	5.9
Percent of total energy in 4 mr beam	93	79	93	84
Number of pulses	-	58,000	-	84,600

Examination of disassembled LTMs after test revealed that degradation was caused by contamination of surfaces in the laser path within the resonator, principally the two end reflectors. Cleaning the mirror surface and the output end of the laser rod restored the modules to their original performance.

2.1.3.4 Pulse Forming Network

The network remains as planned, a 26.5 μf capacitor 27 μh inductor and back-swing protective diode consisting of three discrete parts.

2.1.4 Trigger Circuit Module

2.1.4.1 Packaging

The Trigger Circuit Module, shown in Figure 2-7, is mounted to the battery container at the front of the HHLR as shown in Figure 2-3. This module includes the trigger circuit, the dump circuit, the inductor, and the trigger transformer. The module comprises a printed circuit board to which are mounted most of the discrete parts, a sheet-metal mounting plate, and an inductor sub-module. Two large components, the trigger transformer and a capacitor, are mounted on and staked to the sheet-metal mounting plate for convenience of location and structural rigidity. The printed circuit board is coated with a red conformal coating which provides moisture protection and warning of high voltage. The inductor is a physical entity which is separate from the printed circuit board.

A post at the end of the battery container serves as a common mount for the inductor and the (approximate) center of the printed circuit board. One edge of the printed circuit board is supported by the sheet-metal mounting plate which, in turn, is attached to a corner of the battery container. Thus, the printed circuit board is supported at its center and along one edge.

Interconnections from the printed circuit board to the inducator, the dump switch, the power supply, and the high voltage return point are made by hard wire; all others, by flexible printed wiring terminated at solder terminals. Weight of the Trigger Circuit Module is approximately 0.21 pounds.

2.1.4.2 Trigger Circuit

The trigger circuit is the same as described in Section 2.4 pp 2-81 thru 2-103 of the Design Plan. No changes were made to the trigger circuit initial design, however a few more components have been added to the printed circuit board which are no functional parts of the trigger circuit. The added components are: Prime power fuse, dump resistor for the PFN, and a choke for the PFN charge voltage. These parts were added to the board because of space availability.

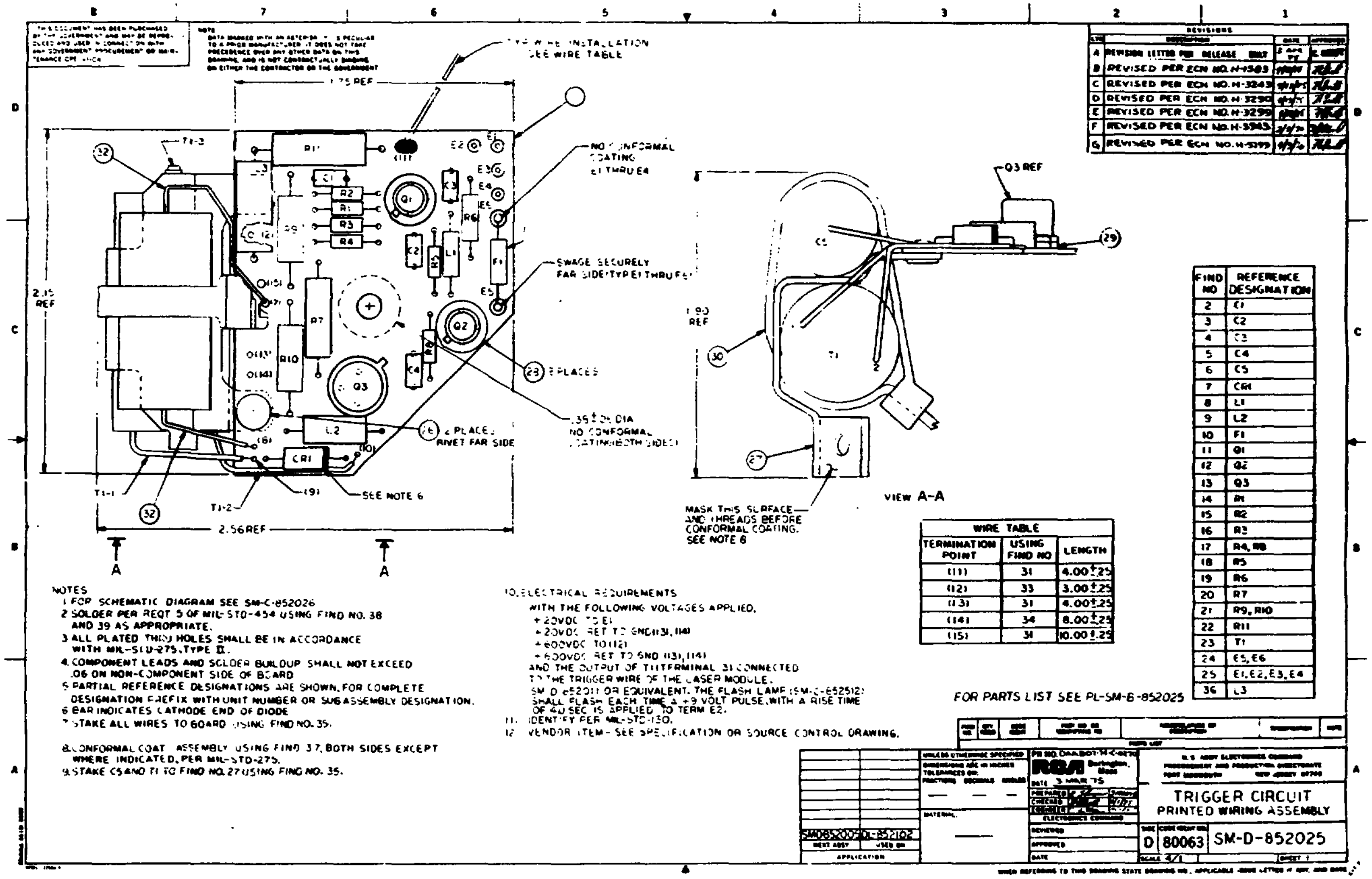


Figure 2-7. Trigger Circuit Module

2.1.5 Detector Pre-Amplifier Module

2.1.5.1 Packaging

The detector pre-amplifier assembly is contained in a TO-8 size can with 12 pin header and optical window in the cover, as planned.

2.1.5.2 Performance Characteristics

The detector is mounted atop a small pedestal on the preamplifier hybrid to place it in a suitable optical location. This mounting method, in conjunction with a redesign of the detector load resistor, has lowered the stray capacity so that the rise time has decreased from 38 nanoseconds (typical) to 25 nanoseconds (typical). All other detector characteristics have remained the same as described in paragraph 2.5 pp 2-105 thru 2-111 of the Design Plan.

2.1.6 Video Amplifier Assembly

2.1.6.1 Packaging

The Video Amplifier Assembly is a hybrid circuit packaged on a 2.25 x 1.25 x 0.035 inch alumina substrate. Active chip devices are mounted under a hermetically sealed enclosure. Only resistors and capacitors are mounted external to this enclosure. Edge mounted clips ground the conductive back plane to several ground points on the active side.

Electrical connections are through lead frame leads hard soldered to the circuitry and bent perpendicular to the substrate. An epoxy bead laid over the lead at the solder joint further immobilizes the pin during assembly and soldering. The entire module is conformally coated with a urethane compound for moisture protection.

This module is bonded to a thin aluminum plate using a semi-flexible, electrically conductive epoxy forming an extended ground plane. Mounting is by conventional screws and washers as shown in Figure 2-8. Two of the four mounting holes are insulated for grounding purposes. The entire assembly weighs 0.05 pounds.

2.1.6.2 Electrical Design

There have been several changes to the video amplifier since the Design Plan (paragraph 2.6 pp 2-115 thru 2-142). These changes are as follows.

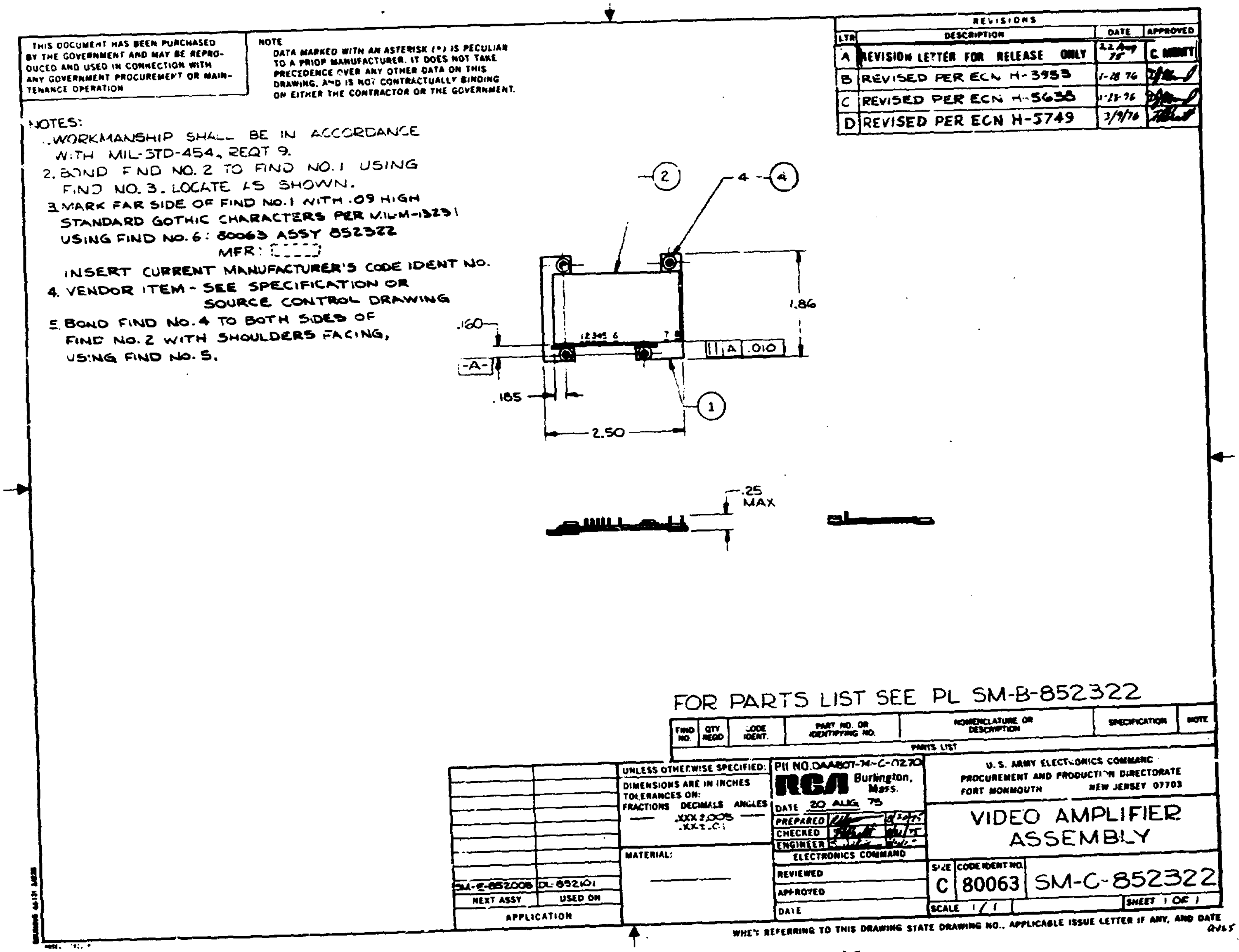


Figure 2-8. Video Amplifier Assembly

2.1.6.2.1 Input Amplifier Bias

In order to reduce the dc output voltage offset due to the input bias current, a resistor of 510 ohms was added to the signal ground side of the input amplifier. This effectively makes the dc impedance seen by the differential inputs equal within the tolerance of the resistors.

2.1.6.2.2 Limiting Diode

A diode was added to the output of the first amplifier to limit the negative recovery overswing of the input amplifier. This was done to improve the recovery time, reduce the minimum target separation, and to eliminate aspurious pulse which occurred in some of the video amplifiers over a very limited range of input signal levels.

The diode selected is actually three diodes connected in series and has a forward voltage drop of 2.1 volts. This is sufficient to prevent the normal offset voltage of the video amplifier from forward biasing the diode and shorting the output for low level signals.

2.1.6.2.3 Frequency Roll-off Capacitance

A 10 picofarad capacitor has been added to the input of the second amplifier stage. This capacitor effectively rolls off the frequency response to eliminate the inherent high frequency peaking of the MC1733CL amplifiers in the low gain mode.

2.1.6.2.4 TPG Modification

The means of obtaining the TPG function was changed by the addition of a transistor switch and two diodes. The transistor switch allows the application of -12 volts to a resistor string to bias off the pair of 2N4391 transistors. The application of this negative voltage allows the use of FET transistors with higher pinch off voltages and the corresponding lower RON. The lower RON provides a higher gain in each video amplifier. In an attempt to slow down or linearize the gain versus range curve two separate capacitors were used in the place of the one in the Design Plan. Thus only one gain stage cuts in at a time producing two smaller steps in place of one large step.

Also, by delaying the turning on of the second stage, the AGC transients generated by the first stage did not see the full gain of the second stage. This minimized the TPG transients generated at the threshold input.

2.1.6.2.5 AGC Time Constant

When the AGC loop was first closed the settling time of the loop was too long. To correct this problem the AGC loop filter capacitor configuration was changed to provide a faster settling time. The settling time is now less than 0.5 seconds.

2.1.7 Power Supply Assembly

2.1.7.1 Packaging

The Power Supply uses discrete electrical parts mounted on two printed circuit boards; one piggybacked. The physical configuration is shown in Figure 2-9. Low voltage connections are through pins at the edges. High voltage and ground connections are through turret terminals. The entire power supply is conformally coated with a urethane compound for moisture protection.

Top and bottom covers provide both electrical shielding and high voltage protection. The top cover is colored red for high voltage warning. The single electrical adjustment is accessible through a hole in this cover.

Mounting is by conventional screws and washers into bosses on the optional assembly. This hardware also serves to attach the covers with the addition of a mounting bracket. Four sets of conventional screws and washers mate top and bottom covers, using special locking nut plates. Electrical connections are through the flexible printed wiring to the low voltage pins and through hard wired connections to the high voltage terminal. The entire assembly weighs 0.25 pounds.

2.1.7.2 Electrical Design

Operation of the Power Supply Assembly is essentially as described in the Design Plan, paragraph 2.7 pp 2-145 thru 2-166 with the following modifications:

(1) Undervoltage cut-out level has been changed to 17.0 ± 1.0 volts dc to assure system operation at an input voltage level of 20 volts dc. This change was accomplished by changing the value of a trim resistor.

(2) A series resistor-capacitor network from the Detector AGC Signal input to ground was added to stabilize the AGC loop and provide acceptable detector high voltage fluctuations.

(3) A resistive divider and an "OR" circuit were added to clamp the minimum detector voltage at approximately 130 volts dc. This function proved necessary to accommodate the high detector noise at low voltage which would otherwise drive the Detector AGC Signal to zero and lock out the circuit.

(4) Transistor Q22 and associated resistors were deleted to eliminate the Detector Voltage output 3.5% step reduction at the time of the Full Charge Signal, which was found to be unnecessary. The turn-off of the detector voltage generator, Q20 - Q21, at the time of the Full Charge Signal is retained.

(5) A separate -12 volt dc output has been provided for the Detector-Preamplifier, through a 51 ohm decoupling resistor, to reduce switching transients and ripple to acceptable levels.

(6) Low voltage output short-circuit protection was provided by the addition of a resistor and two diodes in the 12.8 pre-regulator circuit.

(7) The capacitor charging converter rate was increased to 9 joules in one second and the charge voltage limits were charged to between 650 volts and 850 volts to provide adequate input energy for normal system operation near the middle of this voltage range.

(8) A small inductor was added in series with the input voltage to the low voltage converter and the input capacitor was reduced in value so that the input capacitor charge current through switch contacts would fall within switch ratings.

NOTE
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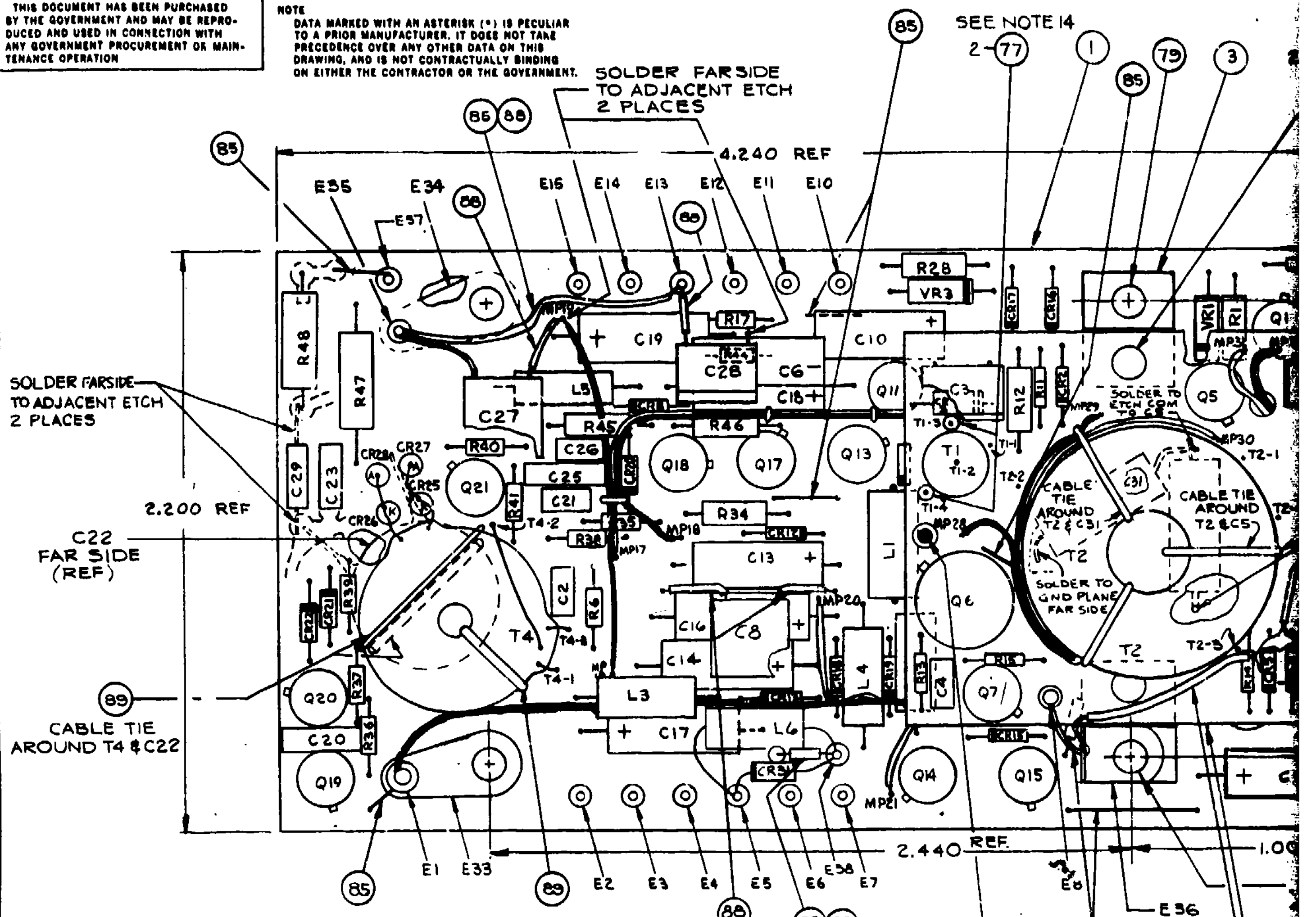

NOTES:
1. FOR SCHEMATIC DIAGRAM SEE SM-D-852272.
2. SOLDER PER MIL-STD-454, REQT 5, USING FIND NO. 91
3. ALL PLATED THRU HOLES SHALL BE PER MIL-STD-275, TYPE II.
4. COMPONENT LEADS AND SOLDER BUILD-UP SHALL NOT EXCEED .06 ON WIRING SIDE OF BOARD.
5. PARTIAL REFERENCE DESIGNATIONS ARE SHOWN, FOR COMPLETE DESIGNATION PREFIX WITH UNIT NUMBER AND SUBASSEMBLY DESIGNATION.
6. BAR INDICATES CATHODE END OF DIODE. A = ANODE ; K = CATHODE
7. IDENTIFY PER MIL-STD-130.
8. DELETED
9. DELETED
10. DELETED
11. TRIM, USING FIND NO. 68(R29), 75(R49) AND 76(R50):
TRIM R29 FOR +12.0VDC AT E2 WITH 24.0VDC APPLIED AT E5 (4.64K ≤ R29 ≤ 14.7K)
TRIM R49 FOR A MAXIMUM VOLTAGE VDC AT E9 (470K ≤ R49 ≤ 2.2 M)
WITH 24.0VDC APPLIED AT E5 AND E7 AND A LOAD CAPACITOR 9 TO 26UF AT E9
TRIM R50 FOR UNDERVOLTAGE CUTOUT OPERATION WITH 7.5VDC APPLIED AT E10 AND 18.3 TO 18.4 VDC APPLIED AT E5 (100K ≤ R50 ≤ 1M)
12. TRANSISTORS AND SQUARE CASE CAPACITORS MOUNTED UPRIGHT TO HAVE .03±.01 CLEARANCE FROM PRINTED WIRING BOARD.

NOTES CONTINUED ON SHEET 2.

WIRE RUN LIST

WIRE	FROM	TO
W1	E1	MP28
W2	MP20	MP23
W3	MP21	MP30
W4	MP22	MP29
W5	MP16	MP19
W6	MP17	MP25
W7	MP18	MP26
W8	MP27	MP32
W9	MP24	MP31

REV STATUS TABLE

SHEET	REV
1	E
2	E
3	A
4	A

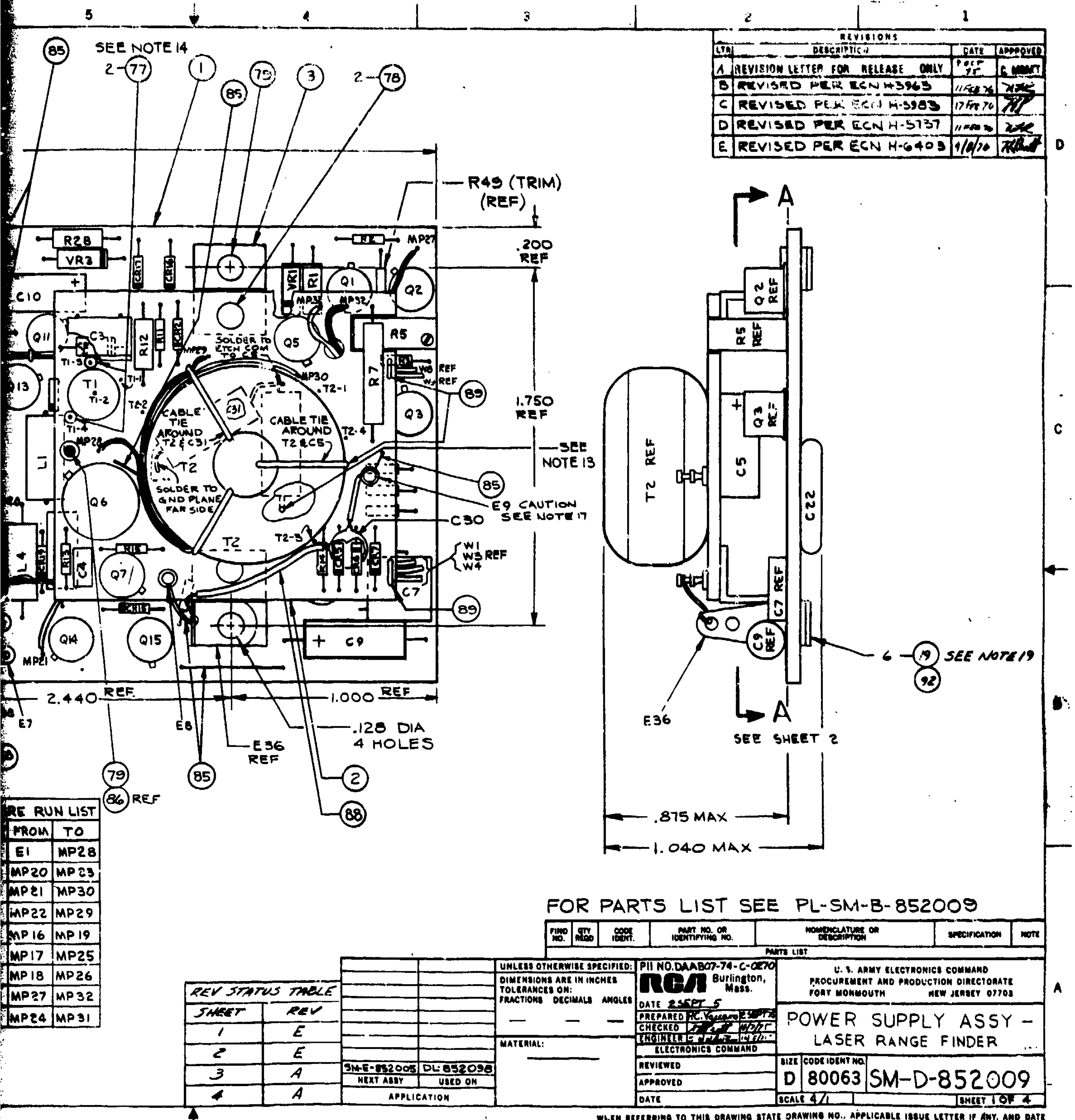

Figure 2-9. Power Supply Assembly. (Sheet 1 of 4)

8	7	6	5	4

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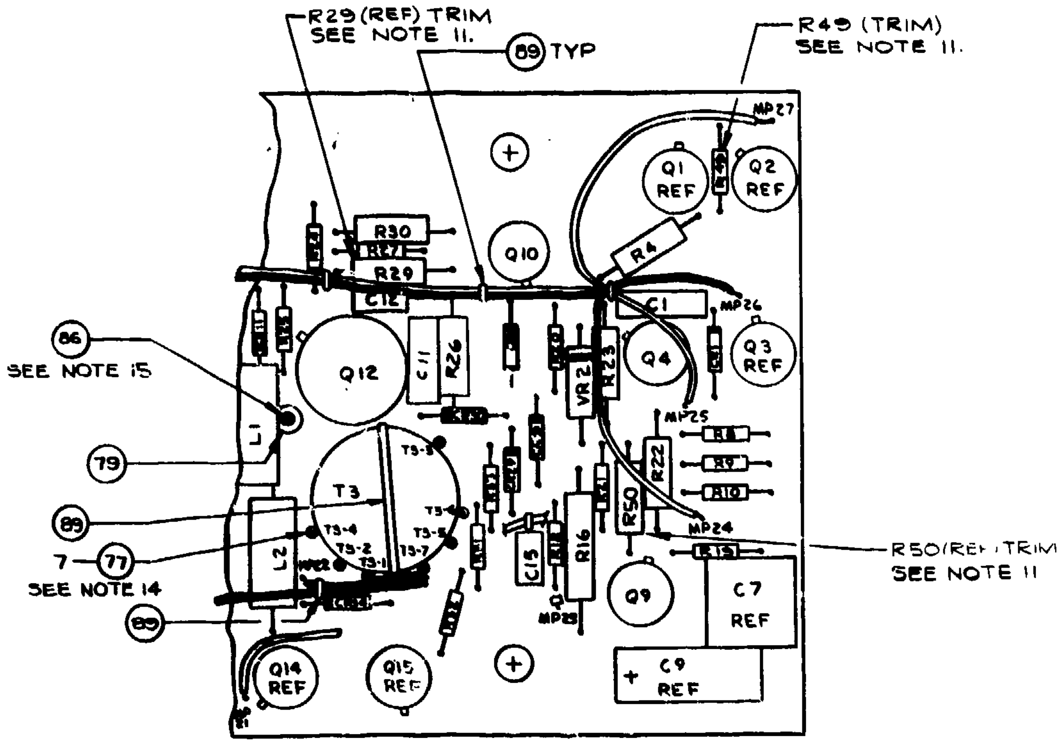

VIEW A-A
FOR COMPONENT IDENTIFICATION UNDER FIND NO. 2 ONLY

FIND NO.	REFE[...] DESIG[...]
4	C1[...]
5	C2, C[...]
6	C3, C7, [...]
7	C[...]
8	C5, C8, [...]
9	C[...]
10	C10, C1[...]
11	C[...]
12	C21, [...]
13	C[...]
14	C[...]
15	C2[...]
16	C27, [...]
17	CR1, [...] CR5-[...] CR29, [...]
20	CR[...]
22	CR25, CR[...]
23	E[...]
24	E1, E8, [...]
25	E2-[...] E10-[...] E37[...]
26	E33[...]
27	L[...]
28	L2, L[...]
29	L[...]
30	T[...]
31	T[...]
32	T[...]
33	T[...]
34	V[...]
35	VR[...]
36	Q[...]

NOTE: REF DES Q[...]

NOTES
(CONTINUED FROM SHEET 1.)

13. CUT LEAD FLUSH WITH SURFACE OPPOSITE COMPONENT AND INSULATE WITH FIND NO. 90.
14. INSERT, SOLDER AND CUT OFF TERMINAL OPPOSITE SIDE.
15. AFTER TRIMMING, ASSEMBLE FIND NOS. 1 AND 2 AND SOLDER FIND NO. 86 TO FIND NO. 79
16. INSULATE FIND NOS. 36 (Q12), 32 (T3) AND 33 (T4) FROM FIND NO. 1 USING FIND NO. 90.
17. CAUTION: DO NOT OPERATE WITHOUT LOAD CAPACITOR AT E9.
18. VENDOR ITEM, SEE SPECIFICATION OR SOURCE CONTROL DWG.
19. BOND FIND NO. 19, 2 EACH AT 3 LOCATIONS, TO FIND NO. 1 USING FIND NO. 92. DO NOT INSTALL FIND NO. 19 AT E34 LOCATION. FIND NO. 19 TO BE CONCENTRIC TO HOLE IN FIND NO. 1 WITHIN .010.

LTR	DESCRIPTION	DATE	APPROVED
A	SEE SHEET 1		
B	REVISED PER ECN H-3963	[illegible]	[illegible]
C	REVISED PER ECN H-3985	[illegible]	[illegible]
E	REVISED PER ECN H-6403	4/8/76	[illegible]

FIND NO.	REFERENCE DESIGNATION	FIND NO.	REFERENCE DESIGNATION	FIND NO.	REFERENCE DESIGNATION
4	C1	37	Q4,Q5,Q7,Q11, Q13,Q20,Q21	70	R36
5	C2, C12			71	R40
6	C3,C7, C25	38	Q1,Q2,Q17,Q18	72	R44
7	C4,C20	39	Q3,Q9,Q10,Q14, Q15, Q19	73	R45
8	C5,C9,C19,C31			74	R46
9	C6,C13	40	Q6	75	R49 SEE NOTE 11
10	C10,C14,C16,C17,C18	41	R47	76	R50 SEE NOTE 11
11	C15	42	R48		
12	C21,C26	43	R32	80	W1
13	C22	44	R34	81	W2,W3
14	C23	45	R35	82	W4,W5,W7
15	C29,C30			83	W6,W9
16	C27,C28,C8			84	W8
17	CR1, CR2 CR5-CR22 INCL CR29,CR30,CR31	48	R1, R23	87	C11
		49	R2, R18, R20		
		50	R3,R8,R9, R39		
		51	R4		
20	CR3	52	R5		
		53	R6,R10, R19, R27		
22	CR25,CR26,CR27,CR28	54	R7		
23	E36	55	R11, R31		
24	E1,E8,E9, E35	56	R12		
25	E2-E7 INCL E10-E15 INCL E37, E38	57	R13, R33, R41		
		58	R14		
26	E33,E34	59	R15, R37		
27	L1	60	R16		
28	L2, L3, L4, L6	61	R17		
29	L5	62	R21		
30	T1	63	R22		
31	T2	64	R24		
32	T3	65	R25, R38		
33	T4	66	R26		
34	VR1	67	R28		
35	VR2, VR3	68	R29 SEE NOTE 11		
36	Q12	69	R30		

NOTE. REF DES Q8 AND Q16 ARE NOT USED

(M)
E 11.

R50(REF) TRIM
SEE NOTE 11

FIND NO.	QTY REQD	CODE IDENT.	PART NO. OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	SPECIFICATION	NOTE

PARTS LIST

NEXT ASSY	USED ON
SM-E-852005	DL-852009

APPLICATION

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES TOLERANCES ON: FRACTIONS — DECIMALS — ANGLES —

MATERIAL:

PII NO. DAAB07-74-C-0270

RCA Burlington, Mass.

DATE 2 SEPT 75

PREPARED R.C. Vaccaro 2 SEPT 75
CHECKED [illegible]
ENGINEER [illegible]

ELECTRONICS COMMAND
REVIEWED
APPROVED
DATE

U. S. ARMY ELECTRONICS COMMAND
PROCUREMENT AND PRODUCTION DIRECTORATE
FORT MONMOUTH NEW JERSEY 07703

POWER SUPPLY ASSY – LASER RANGE FINDER

SIZE D CODE IDENT NO. 80063 SM-D-852009

SCALE 4/1 SHEET 2 OF 4

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Figure 2-9. Power Supply Assembly. (Sheet 2 of 4)

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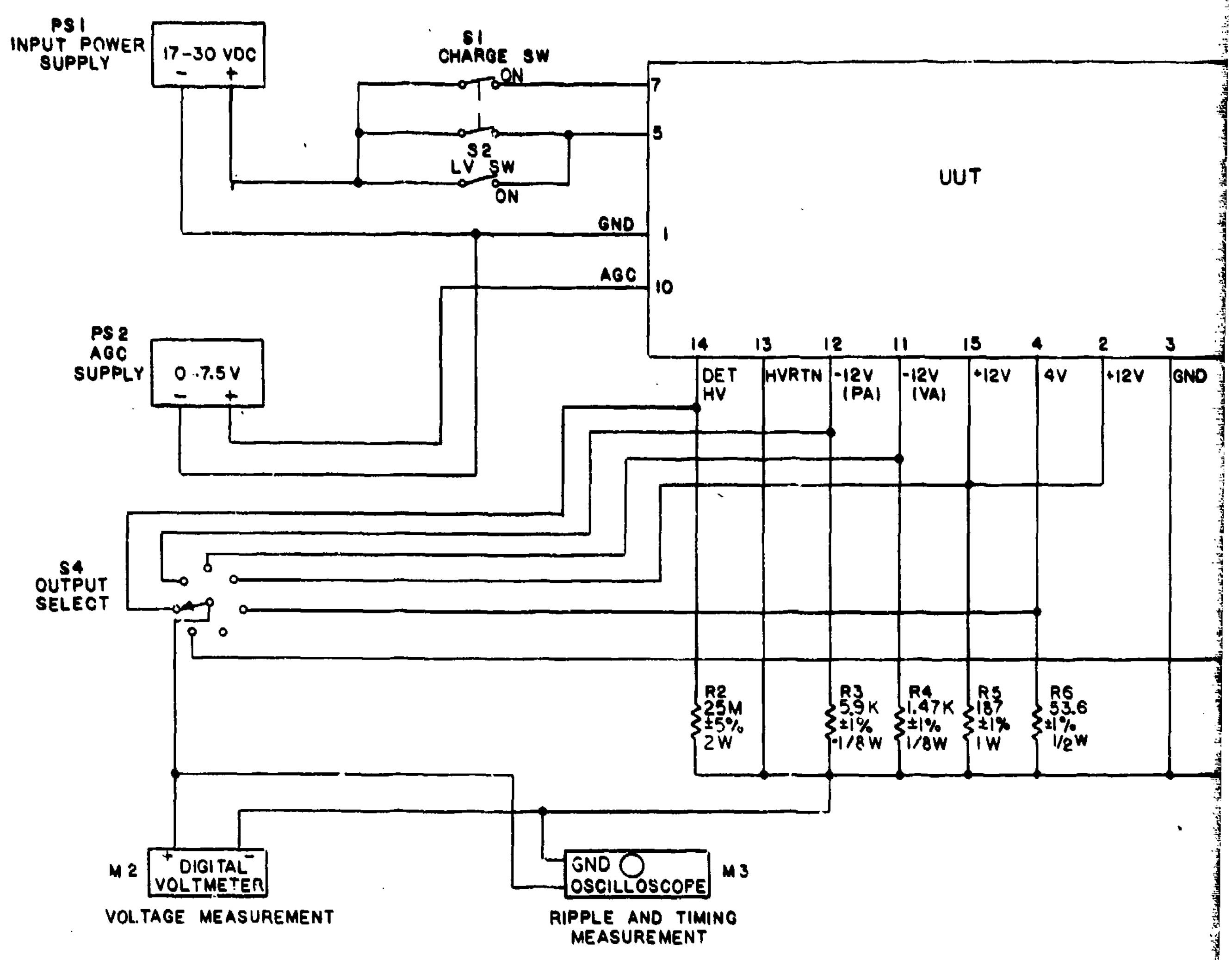

FIGURE 1. TYPICAL TEST CIRCUIT

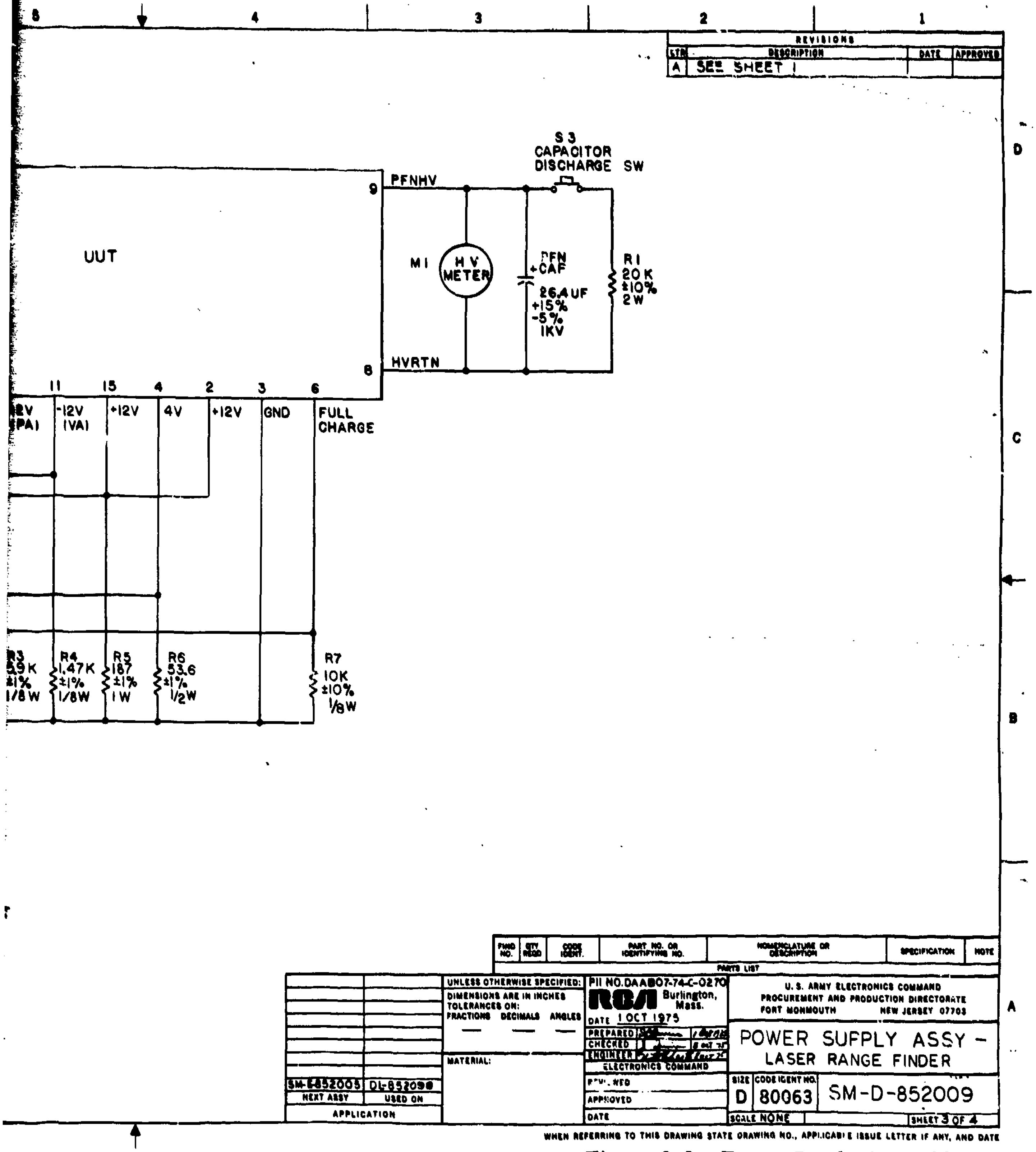

Figure 2-9. Power Supply Assembly.
(Sheet 3 of 4)

8 | 7 | 6 | 5 | 4

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D

11 TEST REQUIREMENTS

11.0 ELECTRICAL CHARACTERISTICS -

THE POWER SUPPLY SHALL HAVE THE CHARACTERISTICS SPECIFIED BELOW WHEN TESTED USING THE CIRCUIT OF FIGURE 1 .

CAUTION: DANGEROUS HIGH VOLTAGE LEVELS EXIST IN THE PFN HV SECTION OF THIS POWER SUPPLY.

11.1 LOW VOLTAGE OUTPUTS

OUTPUTS OF THE LOW VOLTAGE SECTION OF THE POWER SUPPLY ARE SHOWN IN TABLE I.

TABLE I LOW VOLTAGE OUTPUTS

INPUT CONDITIONS	INPUT POWER SUPPLY (VDC)	AGC SUPPLY (VDC)	+12 VDC			-12 VDC (PA)			-12 VDC (VA)			+ 4 VDC		TIMING
			MIN (VDC)	MAX (VDC)	MAX RIPPLE + SPIKES (MV PP)	MIN (VDC)	MAX (VDC)	MAX RIPPLE + SPIKES (MV PP)	MIN (VDC)	MAX (VDC)	MAX RIPPLE + SPIKES (MV PP)	MIN (VDC)	MAX (VDC)	
LV SW ON	20.0	0	11.4	12.6	100	-11.0	-12.4	100	-11.4	-12.6	100	3.6	4.4	OUTPUTS SHALL REACH SPECIFIED LEVEL WITHIN 50 MSEC AFTER LV SW ON
	24.0	0	11.4	12.6	100	-11.0	-12.4	100	-11.4	-12.6	100	3.6	4.4	
	30.0	0	11.4	12.6	100	-11.0	-12.4	100	-11.4	-12.6	100	3.6	4.4	

C

11.2 DETECTOR VOLTAGE

THE DETECTOR VOLTAGE OUTPUT IS CONTROLLED BY THE AGC SUPPLY INPUT AS SHOWN IN TABLE II.

TABLE II DETECTOR VOLTAGE OUTPUT

INPUT CONDITIONS	INPUT POWER SUPPLY (VDC)	AGC SUPPLY (VDC)	DETECTOR VOLTAGE MIN (VDC)	DETECTOR VOLTAGE MAX (VDC)	MAX RIPPLE + SPIKES (VPP)	TIMING
LV SW ON	20.0	2.0	142	158	1	OUTPUT SHALL REACH SPECIFIED LEVEL WITHIN 200 MSEC OF LV SW ON.
	24.0	2.0	142	158	1	
	30.0	2.0	142	158	1	
	24.0	0	130	140	1	
	24.0	4.0	285	315	1	
	24.0	6.0	425	475	1	
	24.0	7.5	520	580	1	
CHARGE SW ON	24.0	7.5	520	580	1	OUTPUT SHALL REACH SPECIFIED LEVEL WITHIN 200 MSEC OF CHARGE SW ON. OUTPUT SHALL BEGIN EXPONENTIAL DECAY TO ZERO VOLTS COINCIDENT WITH "FULL CHARGE SIGNAL." DECAY TIME APPROXIMATELY 250 MSEC.

B

11.3 PFN HIGH VOLTAGE

THE PFN HV SHALL BEG

VOLTAGE LEVELS AND C

TEST	INPUT CONDITI
ADJUSTMENT RANGE	CHARGE ON
CHARGE TIME	CHARGE ON
REGULATION	CHARGE ON

11.4 FULL CHARGE SIGNAL

A LOGIC ONE LEVEL SI

CHARGE SIGNAL SHALL

LOGIC "1"=9.0 TO 12.

LOGIC "0"=LESS THAN

THE RISE TIME OF THE

TEST PROCEDURE:

TURN CHARGE SW ON.

REPEAT FOR ADDITIONA

11.5 UNDERVOLTAGE CUT-O

THE POWER SUPPLY SH

TEST PROCEDURE:

SET INPUT POWER SUP

TO RESET UNDERVOLTA

A

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED
A	SEE SHEET 1		

+4 VDC		
MIN (VDC)	MAX (VDC)	TIMING
.6	4.4	OUTPUTS HALL REACH SPECIFIED LEVEL WITHIN 50 MSEC AFTER LV SW ON
.6	4.4	
.6	4.4	

11.3 PFN HIGH VOLTAGE

THE PFN HV SHALL BEGIN CHARGING THE PFN CAPACITOR UPON OPERATION OF CHARGE SWITCH. VOLTAGE LEVELS AND CHARGE TIME ARE SPECIFIED IN TABLE III.

TABLE III PFN HIGH VOLTAGE OUTPUT

TEST	INPUT CONDITIONS	INPUT POWER SUPPLY (VDC)	AGC SUPPLY (VDC)	PFN OUTPUT VOLTAGE R5 CCW (VDC)	PFN OUTPUT VOLTAGE R5 CW (VDC)	CHARGE TIME SEC	REMARKS
ADJUSTMENT RANGE	CHARGE SW ON	20.0	0	≤ 650	≥850	—	TO REPEAT CYCLE: TURN CHARGE SW OFF. MOMENTARILY OPERATE CAPACITOR DISCHARGE SW AFTER EACH CHARGING OPERATION TO COMPLETELY DISCHARGE CAPACITOR.
		24.0	0	≤ 650	≥850	—	
		30.0	0	≤ 650	≥850	—	
CHARGE TIME	CHARGE SW ON	20.0	0	CALCULATED VALUE [illegible]70≤V≤850		≤ 1.0	ADJUST R5 FOR PFN OUTPUT VOLTAGE CALCULATED USING $V = \sqrt{\frac{1X}{\text{PFN CAP}}}$ NOTE: OBSERVE FULL CHARGE SIGNAL ON OSCILLOSCOPE. TRIGGER OSCILLOSCOPE FROM CHARGE SW CLOSURE.
REGULATION	CHARGE SW ON	20.0	0	SUBSEQUENT RE-CHARGING SHALL BE WITHIN 2.5% OF SET VALUE FOR EACH INPUT PWR SUPPLY SETTING			
		24.0	0				
		30.0	0				

11.4 FULL CHARGE SIGNAL

A LOGIC ONE LEVEL SIGNAL SHALL BE GENERATED NOT LATER THAN 10 MILLISECONDS AFTER THE PFN HV REACHES THE LEVEL SET BY R5. THE FULL CHARGE SIGNAL SHALL REMAIN A LOGIC ONE UNTIL INPUT VOLTAGE IS REMOVED FROM THE POWER SUPPLY. LOGIC LEVELS ARE DEFINED BELOW:

LOGIC "1"=9.0 TO 12.6 VDC

LOGIC "0"=LESS THAN 0.5 VDC

THE RISE TIME OF THE FULL CHARGE SIGNAL SHALL BE LESS THAN 30 MICROSECONDS.

TEST PROCEDURE:

TURN CHARGE SW ON. OBSERVE FULL CHARGE SIGNAL ON OSCILLOSCOPE. TURN CHARGE SW OFF. OPERATE CAPACITOR DISCHARGE SW. REPEAT FOR ADDITIONAL MEASUREMENTS.

11.5 UNDERVOLTAGE CUT-OUT CIRCUIT

THE POWER SUPPLY SHALL NOT GENERATE OUTPUT VOLTAGES WITH THE INPUT POWER SUPPLY SET TO 18.0 VDC.

TEST PROCEDURE:

SET INPUT POWER SUPPLY TO 18.0 VDC. PLACE LV SW ON. OBSERVE ABSENCE OF OUTPUT VOLTAGES. TURN LV SW OFF. TO RESET UNDERVOLTAGE CUT-OUT CIRCUIT SET INPUT POWER SUPPLY TO 20.0 VDC. PLACE LV SW ON. OBSERVE OUTPUT VOLTAGES PRESENT.

FIND NO.	QTY REQD	CODE IDENT.	PART NO. OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	SPECIFICATION	NOTE

PARTS LIST

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APPLICATION

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MATERIAL:

PII NO. DAAB07-74-C-0270

RCA Burlington, Mass.

DATE 1 OCT 1975

PREPARED / CHECKED / ENGINEER

ELECTRONICS COMMAND

REVIEWED

APPROVED

DATE

U. S. ARMY ELECTRONICS COMMAND PROCUREMENT AND PRODUCTION DIRECTORATE FORT MONMOUTH NEW JERSEY 07703

POWER SUPPLY ASSY — LASER RANGE FINDER

SIZE D CODE IDENT NO. 80063 SM-D-852009

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Figure 2-9. Power Supply Assembly. (Sheet 4 of 4)

(9) Bypass capacitors were added from the output voltage terminals to ground to reduce the switching pre-regulator spikes to acceptable limits.

2.1.8 Range Counter Display Assembly

2.1.8.1 Packaging

The Range Counter/Display Assembly is as described in the Design Plan, paragraph 2.8.1, pp 2-169 thru 2-170 with the modifications noted as follows:

(1) The electrical connections are through lead frame leads, rather than pins, which are immobilized by an epoxy bead at the pin solder joints.

(2) The readout mounting and wiring technique is as described in the fourth paragraph of the Design Plan, not as in the next to last paragraph.

(3) Additional lead frame leads are provided along one edge of the substrate for tie-in to a remote display. Since these pins are not presently used, the pins are taped to prevent inadvertent shorting.

2.1.8.2 Electrical Design

Operation of the Range Counter/Display Module is as described in the Design Plan, paragraph 2.8.2, pp 2-171 thru 2-183. The following modifications were required, however, to guarantee satisfactory performance.

(1) Current limiting resistors were added in series with the FULL CHARGE and STOP inputs to limit input current levels to the LSI input protection circuit limits.

(2) The case of the 15 Mhz quartz crystal was grounded to reduce radiation of the high frequency.

(3) Resistor R7, in the 2.5 kHz oscillator circuit, was replaced with a short circuit to reduce the impedance at the input of U60 and improve its noise immunity.

The displays remain as described in the Design Plan without modification.

2.1.9 Controls, Interlocks, and Fault Isolation

2.1.9.1 Description of Controls and Interlocks

The description of controls and interlocks in paragraph 2.9.1, pp 2-222 thru 2-225, of the Design Plan is accurate except for detail changes described in the paragraphs below.

In Table 2-23 of the Design Plan, R2 is described as a rotary bar knob; however, it has been changed to a round knob.

The Power On/Off switch, S1, is a type SR-20 switch per MIL-S-3786, and is made by Grayhill. It is specified for 0.5 in-lbs. minimum rotational torque for a 60 degree throw and has current and voltage capability as stated in the Design Plan. Pressure-sealing of the through-panel leak paths is accomplished by use of a shaft seal boot which is identical to an M5423/09-03 boot except that the insert has 0.250-28 threads rather than 0.250-32 threads.

The characteristics of the interlock switches are detailed in the Design Plan. However, a change has been made in their mounting location. The interlock switches are mounted on the battery container rather than on the trigger circuit board and are directly actuated by a cast-in tab on the inside of the cover. This location is physically more convenient than the trigger circuit module printed circuit board. For the reasons stated in the Design Plan, no integral feature is provided to defeat the switches. As one of its design features, the STE has a simple, hand-operated, spring loaded mechanism which is used to defeat the interlock switches when the HHLR is tested with its cover off.

Reticle light brightness is controlled by R2, a 0.5 diameter, infinite resolution potentiometer designed to withstand the environments specified in MIL-R-94. The potentiometer has silicone panel and shaft seals which are effective to 15 psig.

No specific EMI pressure seals are required for any of the switches or controls. There is sufficient continuity of conductive paths inherent in the designs to preclude the need of additional EMI protection as part of the boots or shaft seals.

The push button assemblies use small, silicone rubber boots per M5423/10-01. These provide pressure seals to 15 psig. The shafts of R1 and R2 are further sealed by standard rotary shaft sealing boots per M5423/09-03. These boots are silicone rubber and act as panel seals as well as shaft seals.

The control knob used for R1 is a shaped, custom, aluminum knob; those used for S1 and R2 are standard knobs per MS91528. The knob used for S1 is pointed; the knob used for R2 is round. Attachment of the knobs is by set-screws onto flatted shafts.

2.1.9.2 Electrical Design

2.1.9.2.1 Controls and Interlocks

Controls and interlocks remain as described in the Design Plan, paragraph 2.9.2, pp 2-226 thru 2-230 with one modification. A 10 Kilohm resistor was connected across the contacts of the FIRE switch which apply input voltage to the high voltage converter section of the power supply. This resistor provides a charge path for the power supply filter capacitors and assures that the current ratings of the switch are not exceeded.

2.1.9.2.2 Fault Isolation

Fault isolation to a module is accomplished by monitoring the rangefinder voltages, except high voltages, and timing and control signals at the module input and output pins. The PFN high voltage and Detector high voltages are monitored as low voltage analogs at the Trigger Circuit and Power Supply module respectively.

The laser transmitter output energy is monitored as described in the Design Plan except that the red indicator lamp illuminates for energy levels below 8.0 millijoules. The test set also generates a fixed range, simulated return at 4800 $\pm$ 200 meters and at near minimum detectable signal level to check receiver sensitivity and range counter operation.

2.1.10 Battery BB-516( )/U

The battery specified for the HHLR is a rechargeable nickel cadmium assembly of 20, 1/3 "A" size cells. Its nominal voltage is 24V and its capacity is about 150 ma. hrs. The battery is approximately 1.4 inches across the flats with a 0.312 radii on corners. Its length is 3.625" over the contacts which are centered on the ends. The positive contact is 0.375" in diameter and the negative contact is 0.936" in diameter.

2.1.11 Weight

A primary requirement of the HHLR design was to achieve a unit weight of less than 5 pounds. Actual weights of four current HHLRs are between 4.5 and 4.6

pounds, mostly on the high side. It is not unexpected that a given unit will exceed 4.6 pounds, but the 5 pound limit has been met.

The weight summary in Table 2-1 shows three columns of data: (1) proposal baseline weight, (2) baseline weight at the time of the writing of the Design Plan, and (3) final or current weight. Although the latter cannot be correlated with the former in every case, it presents an indication of accuracy of initial calculation.

Table 2-1. HHLR Weight Summary

Item	Proposal Baseline Wt. in Lbs.	Design Plan Baseline Wt. In Lbs.	Current Wt. In Lbs.
Control Panel	0.34	0.56 ± 0.01	0.99 See Note (1)
Battery Compartment	--	0.08	See Note (1)
Cover	0.53	0.54 ± 0.06	0.54 (including windows)
Windows	--	0.06	
Power Supply	0.25	0.25	See Note (1)
Range Counter/Display Module	0.22	0.07	0.03
Trigger Circuit Module	0.18	0.15	0.12
Video Amp Module	--	0.04	0.03
Detector/Preamp Module	0.10	0.02	See Note (2)
Battery (Gov't Specified)	0.61	0.55	0.49
Optics Assembly	1.38	1.56 ± 0.04	1.52
Laser Transmitter	0.09	0.09	0.11
PFN Capacitor	0.21	0.25	0.25
PFN Inductor	0.19	0.10	0.08
Reticle Light Assembly	0.02	0.01	0.00
Control Panel Parts	0.24	0.22	0.22 See Note (3)
Connector	0.08	--	--
High Voltage Leads	0.08	0.03	0.03 See Note (3)
Interlock Switch	0.01	--	--
Wire	0.17	0.07	See Note (1)
Lens Protector	--	0.03	0.02
Miscellaneous	0.18	0.30	0.28 See Note (3)
TOTAL	4.88	4.98 ± 0.011	4.71

Notes: (1) -- This weight includes the control panel, the power supply, the battery compartment, the PFN diode, and all of the flexible wiring.

(2) -- Included in Optics Assembly Weight.

(3) -- Estimated per the Design Plan calculations.

2.2 ACCESSORIES

2.2.1 Carrying Case

The final design of the carrying case is shown in Figure 2-10. It has all of the features listed in Paragraph 5.1.2, p 5-1 of the Design Plan but differs in final form factor from Figure 5.1 of the design plan. The altered form factor accommodates the fabrication processes for the material chosen for the carrying case: A.B.S. (Acrylonitrile Butadiene Styrene).

2.2.2 Transit Case

The final design of the Transit case is shown in Figure 2-11 and contains all of the features and provisions listed in Paragraphs 5.2.1 and 5.2.2, pp 5-3 thru 5-5 of the Design Plan. It differs only in final form factor from Figure 5.3 of the Design Plan. The changes to the form factor were made to decrease the perimeter distance of the closure which made it easier to provide a pressure seal and decreased the cost of the transit case.

The transit case successfully passed all of the environmental tests listed on Page 5-4 of the Design Plan, however minor evidence of corrosion was noted around the humidity indicator after the humidity test. The corrosion was traced to an incompatability of materials between the indicator housing and its mounting hardware, and all of the indicators have been replaced.

2.2.3 Adaptor Brackets

The adaptor brackets are as described in Section 5.3, pp 5-8 thru 5-17 of the Design Plan and as below.

(1) The designation of the night sight for which an adaptor has been designed was changed from AN/TAS-2 to AN/TAS-6.

(2) The adaptor designed for the AN/PVS-4 night observation device is useable as well with the AN/TVS-5 NOD.

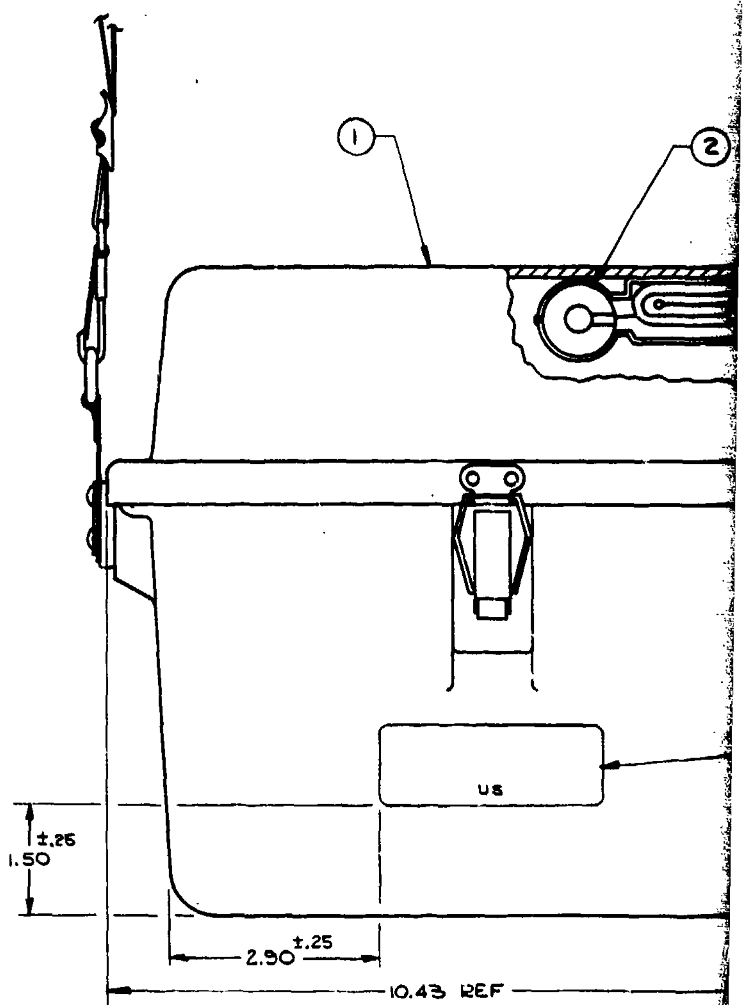
(3) Referring to Paragraph 5.3.2 of the Design Plan, the design, shown in Figure 5-5 of that report, includes cast-in surfaces which are used as machining references. It has been determined that sand casting is the preferred process for this adaptor on a cost basis.

(4) Figures 2-12 and 2-13 of this report show the latest version of these adaptors and supersede the corresponding Figures 5-4 and 5-5, in the Design Plan.

8	7	6	5	4

NOTE
DATA MARKED WITH AN ASTERISK (*) IS PECULIAR TO A PRIOR MANUFACTURER. IT DOES NOT TAKE PRECEDENCE OVER ANY OTHER DATA ON THIS DRAWING, AND IS NOT CONTRACTUALLY BINDING ON EITHER THE CONTRACTOR OR THE GOVERNMENT.

NOTES:
1. WORKMANSHIP SHALL BE IN ACCORDANCE WITH MIL-STD-454, REQT 9.
2. VENDOR ITEM - SEE SPECIFICATION OR SOURCE CONTROL DRAWING



D

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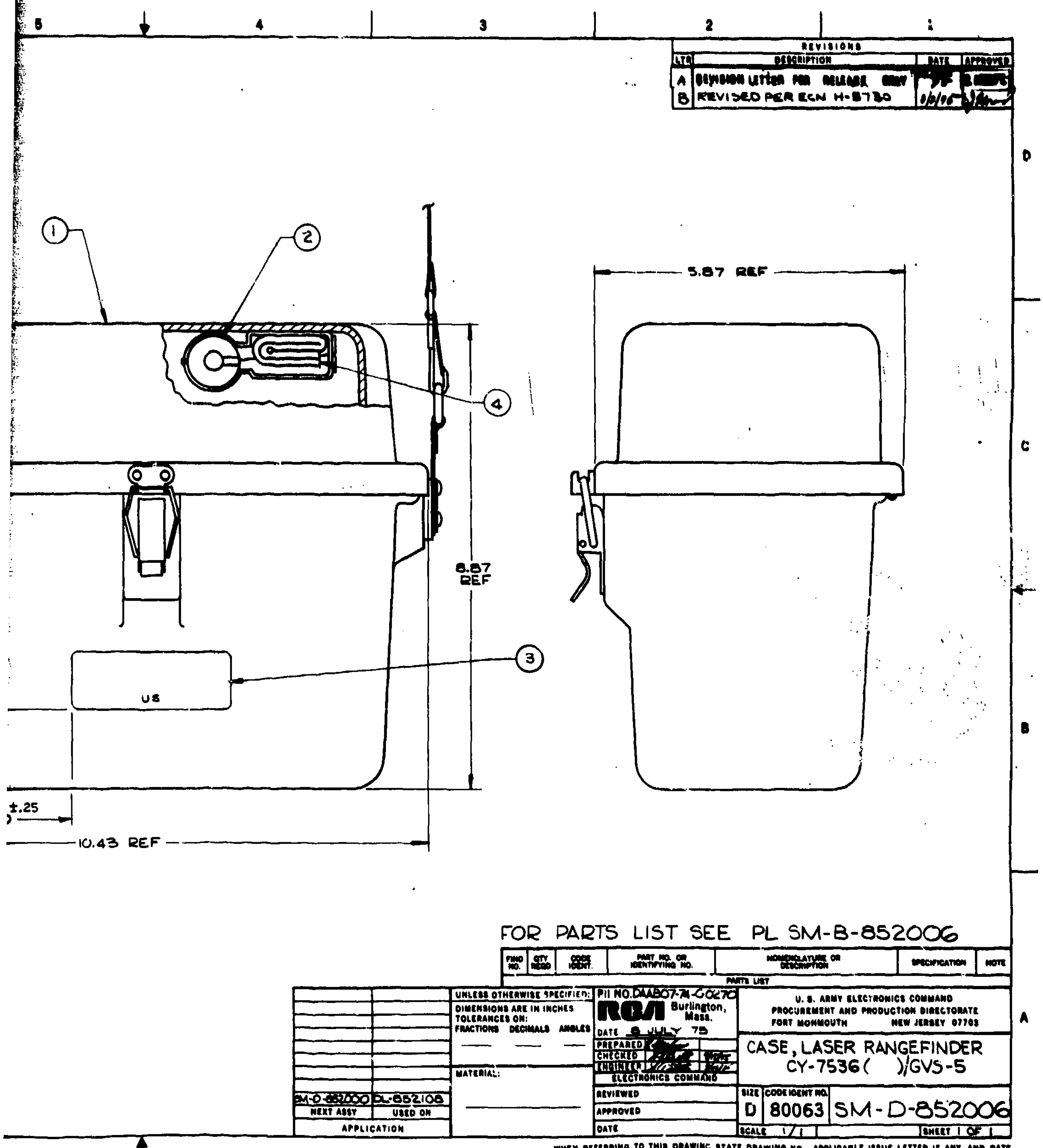

Figure 2-10. Carrying Case

NOTE
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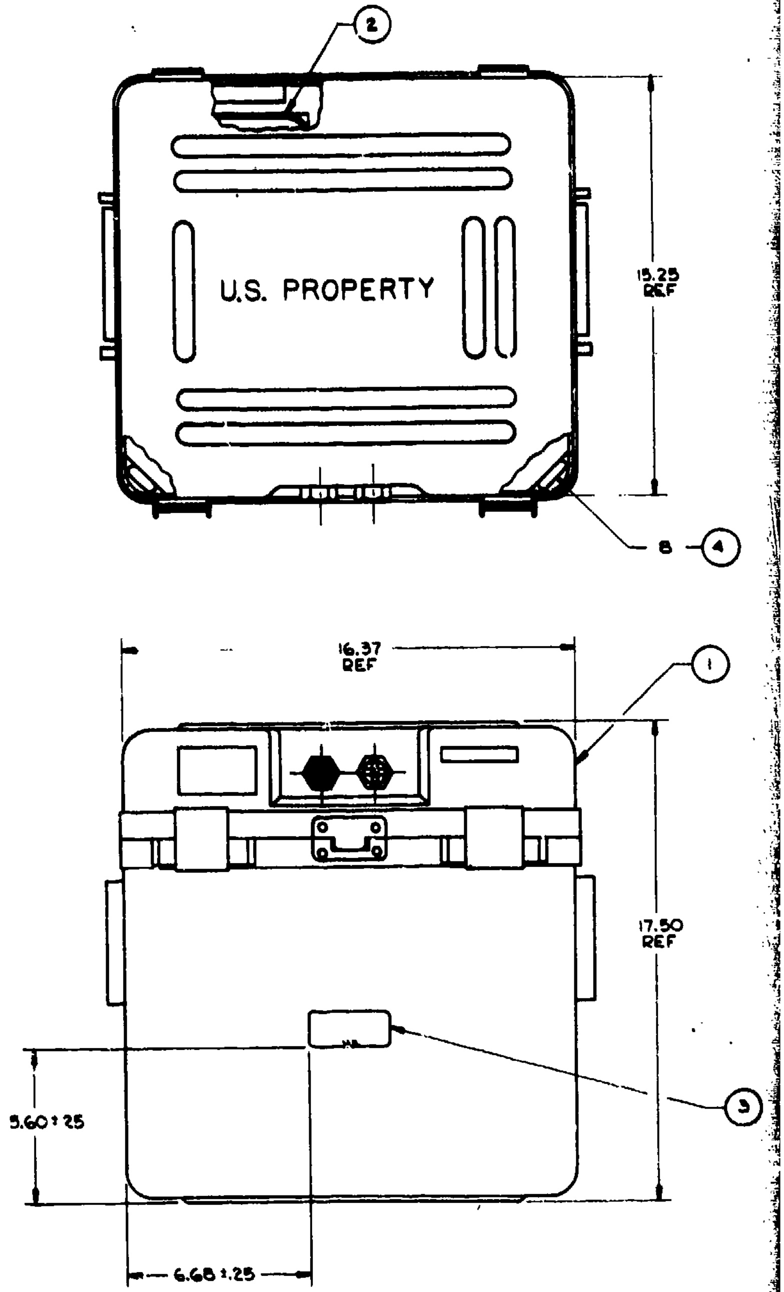
NOTES:
1. WORKMANSHIP SHALL BE IN ACCORDANCE WITH MIL-STD-454, REQ 9.
2. VENDOR ITEM-SEE SPECIFICATION CONTROL DRAWING.



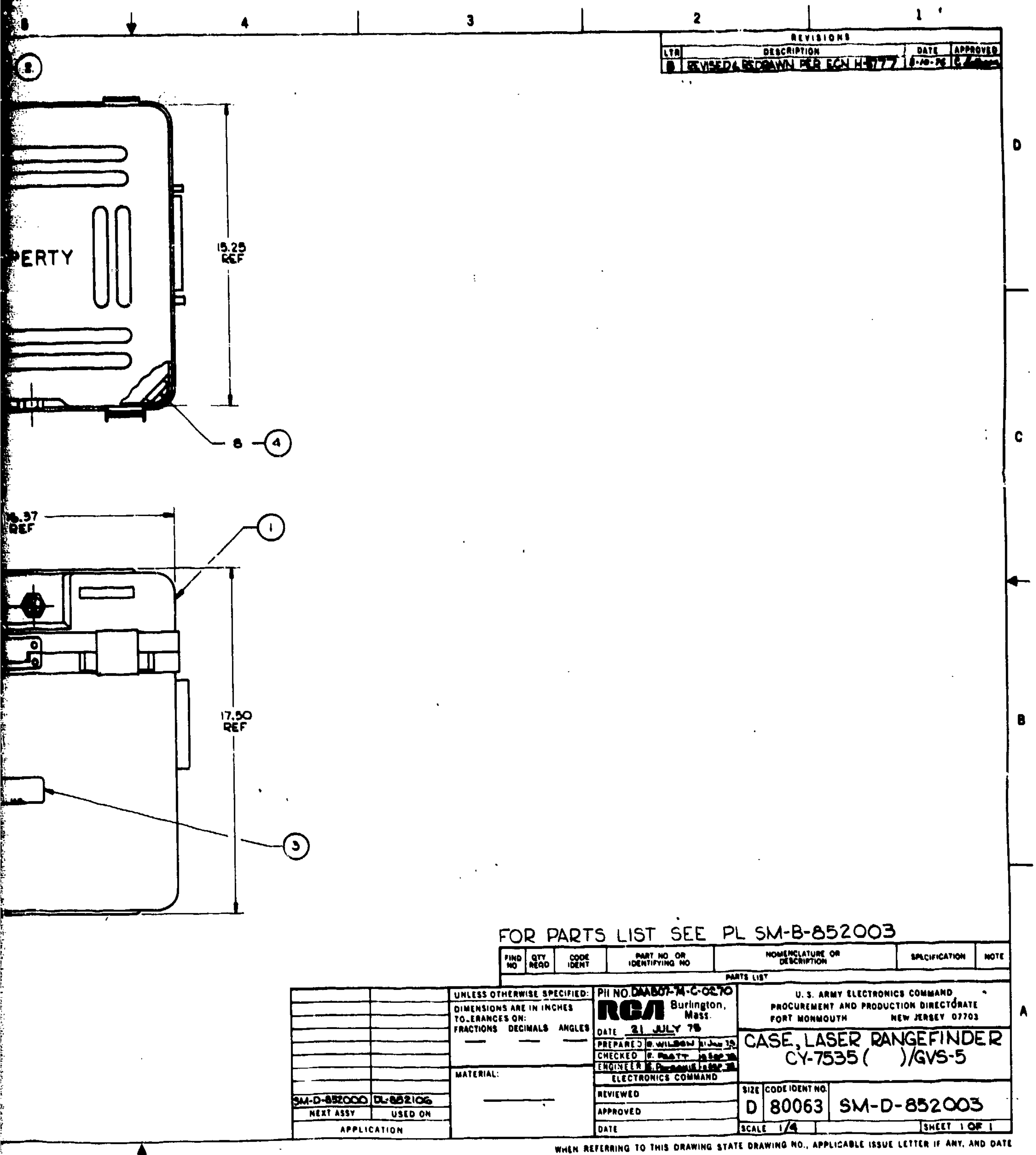


Figure 2-11. Transit Case

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NOTE
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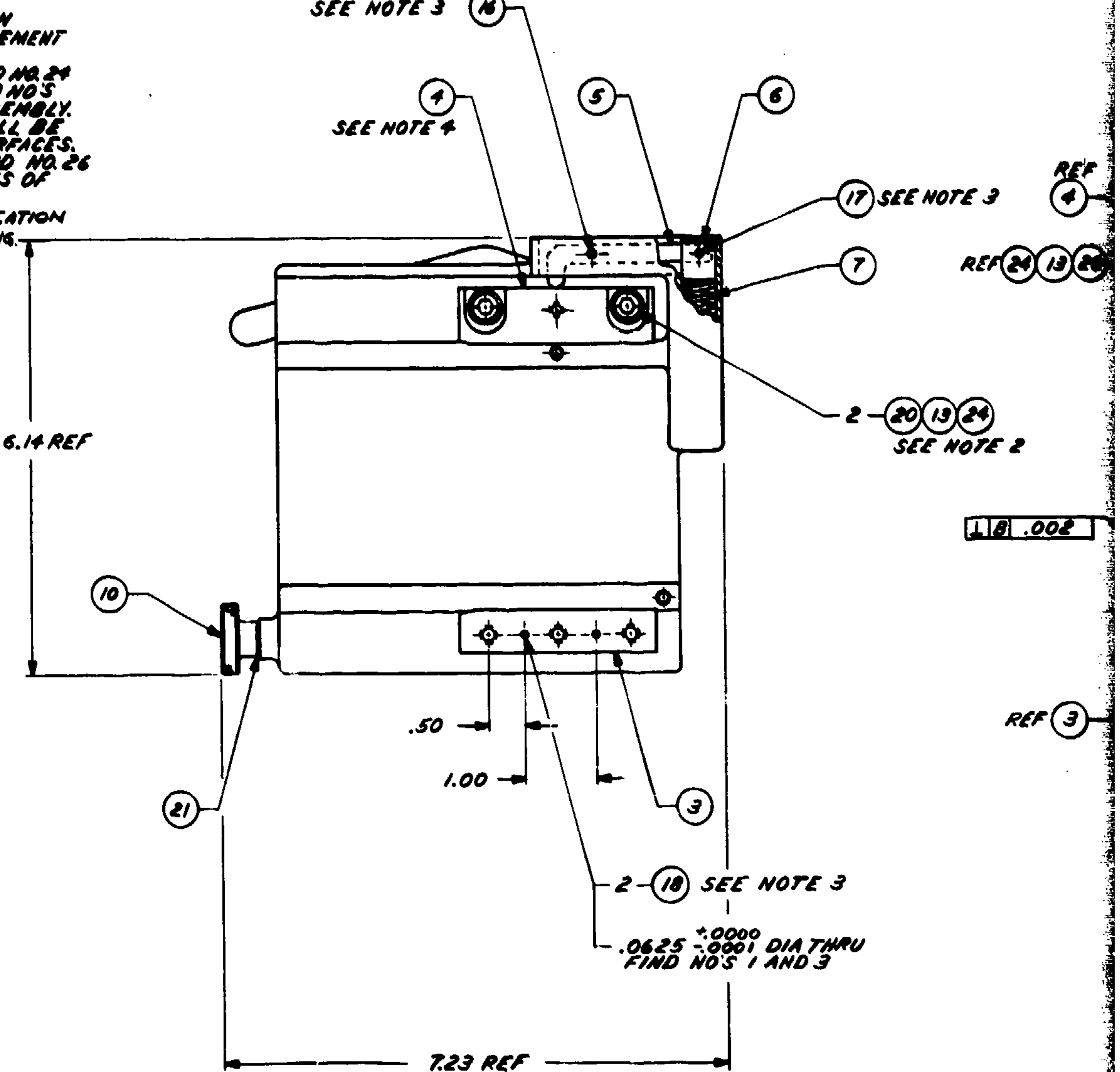
NOTES:
1. WORKMANSHIP SHALL BE IN ACCORDANCE WITH REQUIREMENT 9 OF MIL-STD-454.
2. APPLY A COATING OF FIND NO. 24 TO THE THREADS OF FIND NO'S 12 THRU 15 PRIOR TO ASSEMBLY.
3. FIND NO'S 16 THRU 19 SHALL BE FLUSH OR BELOW ALL SURFACES.
4. APPLY A COATING OF FIND NO. 26 TO THE SLIDING SURFACES OF FIND NO'S 4 & 12.
5. VENDOR ITEM, SEE SPECIFICATION OR SOURCE CONTROL DRAWING.



REV STATUS

SH	REV	SH	REV
1	D		
2	D		

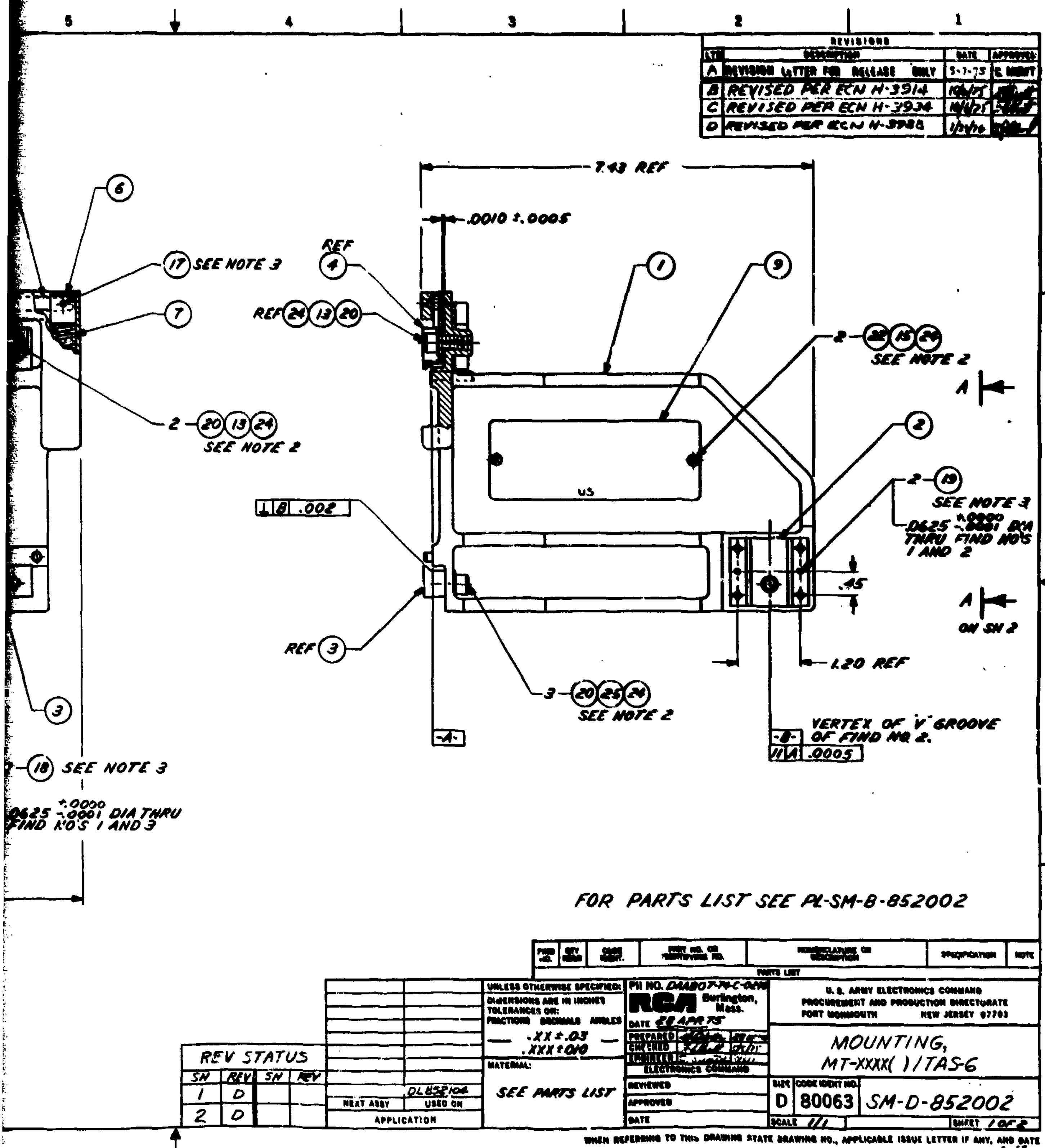


Figure 2-12. AN/TAS-6 Adapter Bracket
(Sheet 1 of 2)

NOTE

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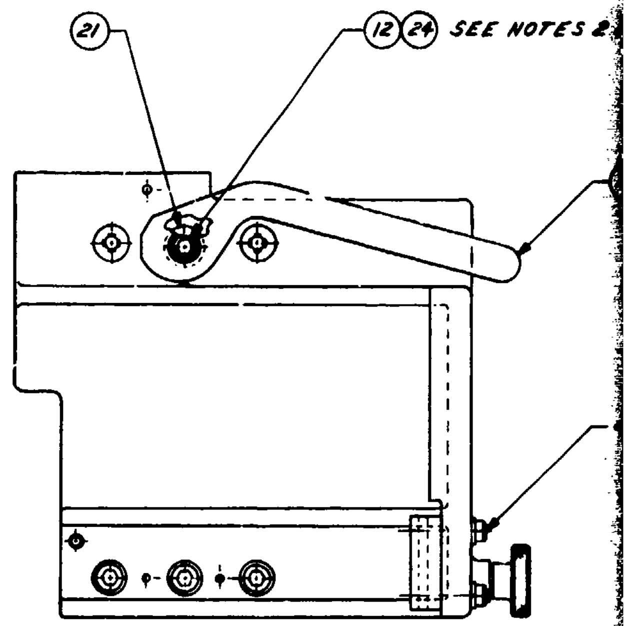

VIEW A-A
SEE SHEET 1

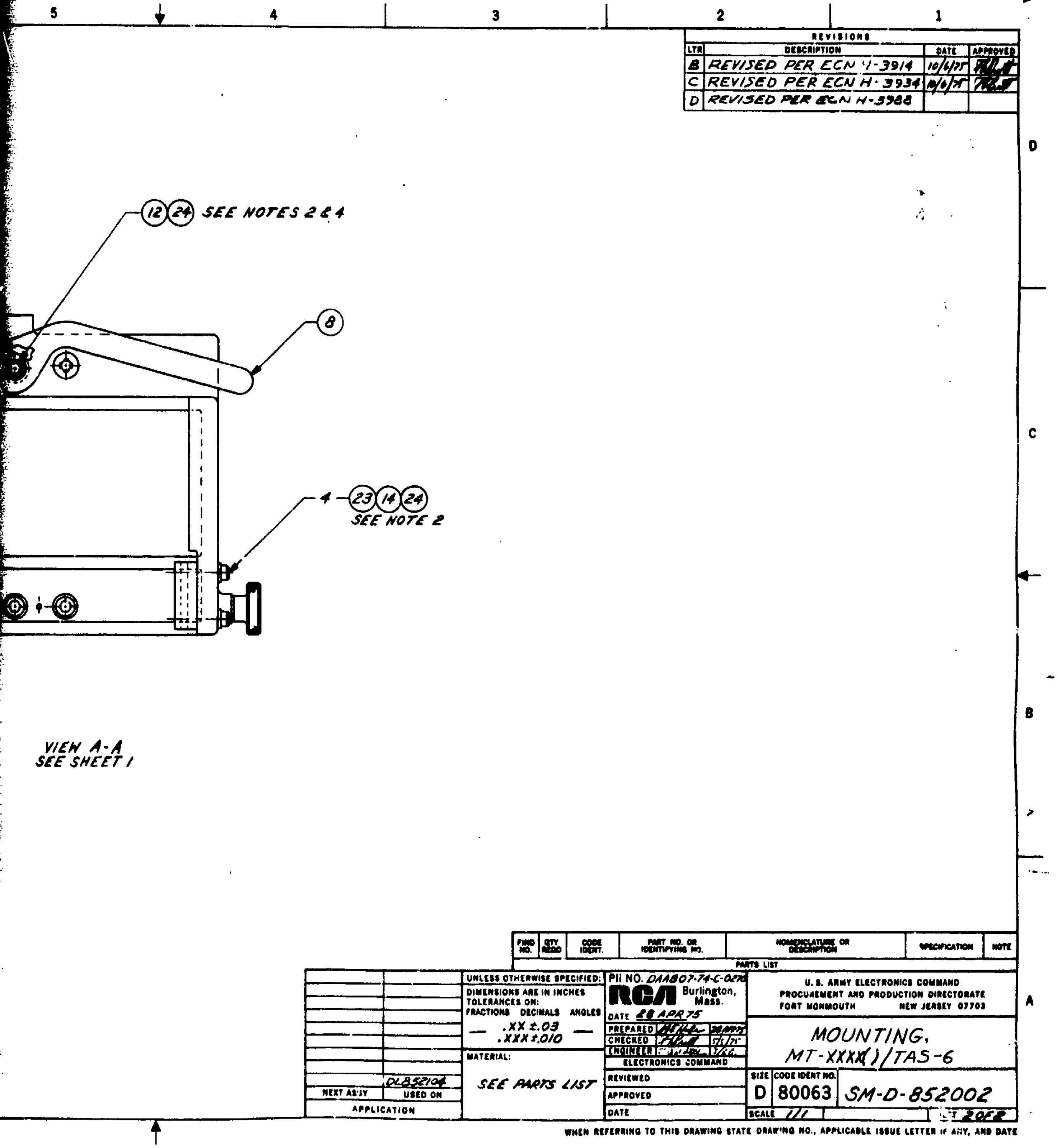

Figure 2-12. AN/TAS-6 Adapter Bracket
(Sheet 2 of 2)

8 | 7 | 6 | 5 | 4

NOTE

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NOTES:

1. WORKMANSHIP SHALL BE IN ACCORDANCE WITH REQUIREMENT 9 OF MIL-STD-454.
2. APPLY A COATING OF FIND NO. 8 TO THE THREADS OF FIND NO. 5 PRIOR TO ASSEMBLY.

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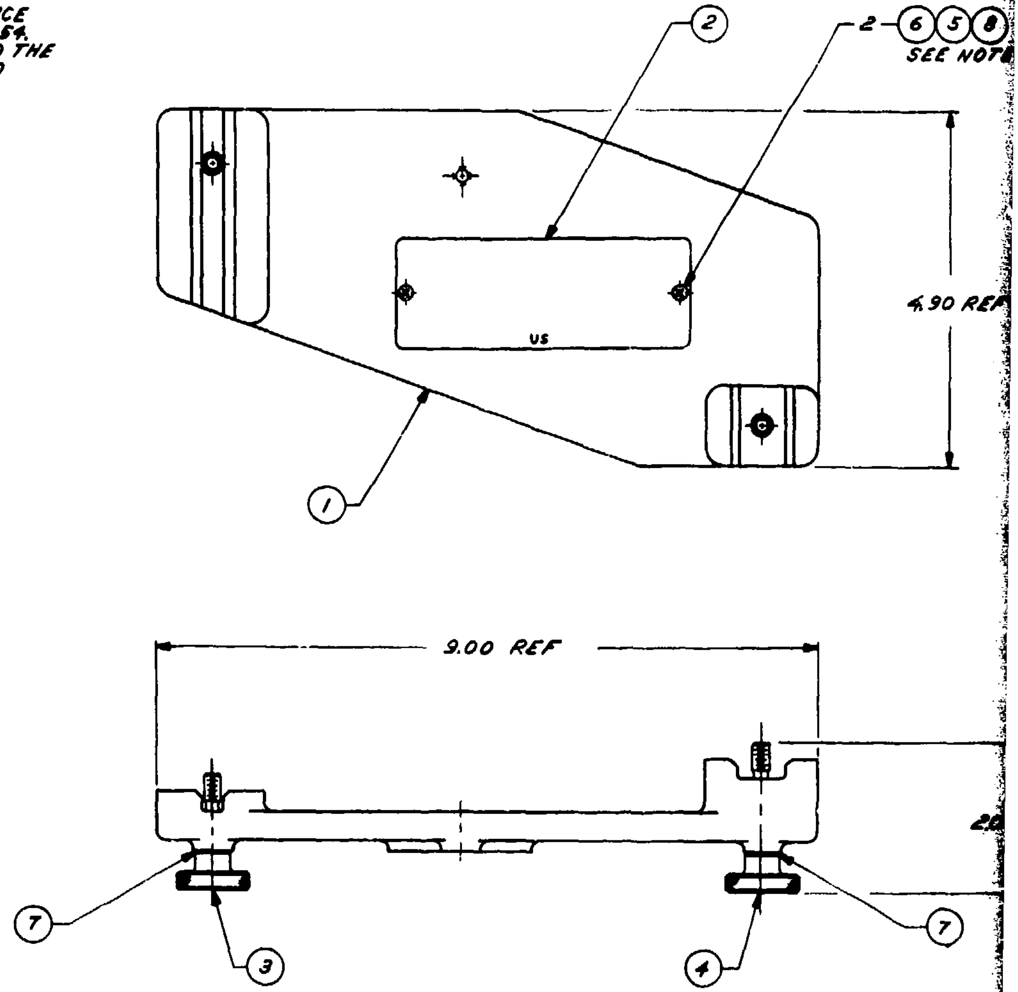

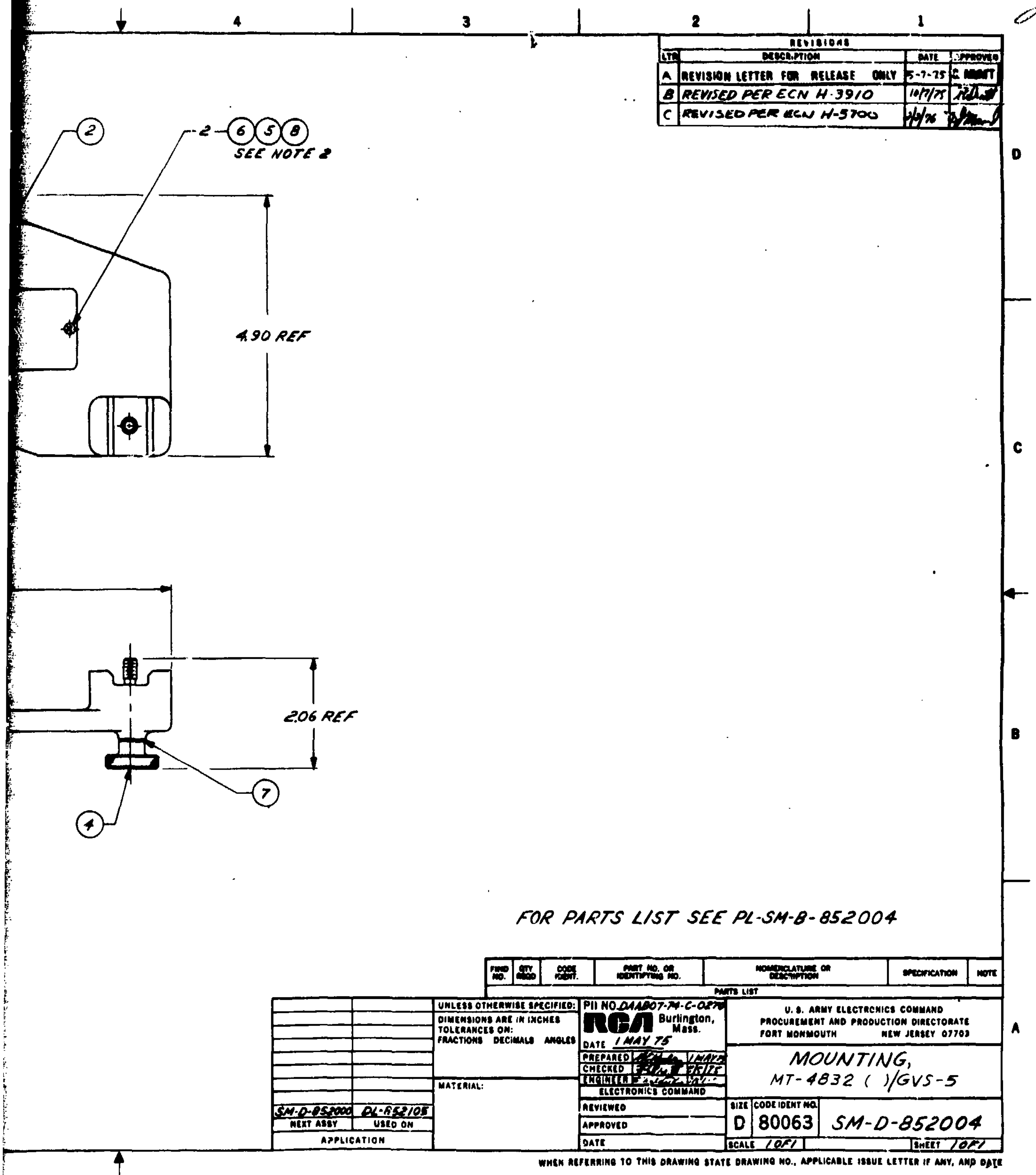

Figure 2-13. AN/PVS-4 and AN/TVS-5 NOD Adapter Bracket

2.2.4 Remote Power Cable

2.2.4.1 Packaging

The remote power cable assembly is configured to directly replace the battery in the battery container. As shown in Figure 2-14 it comprises an electronic subassembly, a threaded cap, an external cable and battery clips.

The electronic subassembly consists of an investment-cast aluminum chassis to which are mounted the large discrete parts and a small printed-circuit board. An internal cover plate which screws onto the casting provides an enclosed EMI filter compartment.

An outer cover identical in size and shape to the battery is bonded and fastened to the chassis. After final electrical test the assembly is potted with a transparent RTV silicone.

To complete the environmental protection of the electronics, the external cable entry is potted with a polysulphide elastomer. The EMI filter compartment is filled and the potting extended to the exposed end of the cable outer jacket.

The external threaded cap engages the threads in the control panel in the same way as the HHLR battery cap. In conjunction with its compression spring, it completes the electrical ground path to the control panel. A rotary seal between the threaded cap and the chassis provides environmental protection for the interface to the chassis. An O-ring provides the seal to the control panel.

2.2.4.2 Electrical Design

The present Remote Power Cable meets the electrical requirements described in paragraph 5.4, pp 5-18 thru 5-21 of the Design Plan, however, the circuit differs somewhat.

The laser rangefinder is required to operate with +20 vdc at the input of the Remote Power Cable. The 2.5 V minimum voltage drop across the Remote Power Cable shown in the Design Plan would have caused the power supply undervoltage cut-out circuit to actuate and thus prevent system operation. The voltage drop was due mainly to the Darlington pair pass transistor Q1 and also to the reverse polarity protection diode CR1. The revised circuit is similar to the original circuit but uses a single PNP pass transistor instead of the Darlington pair to assure system operation for inputs down to +20 V. Figure 2-15 is the Remote Power Cable electronic schematic.

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NOTE
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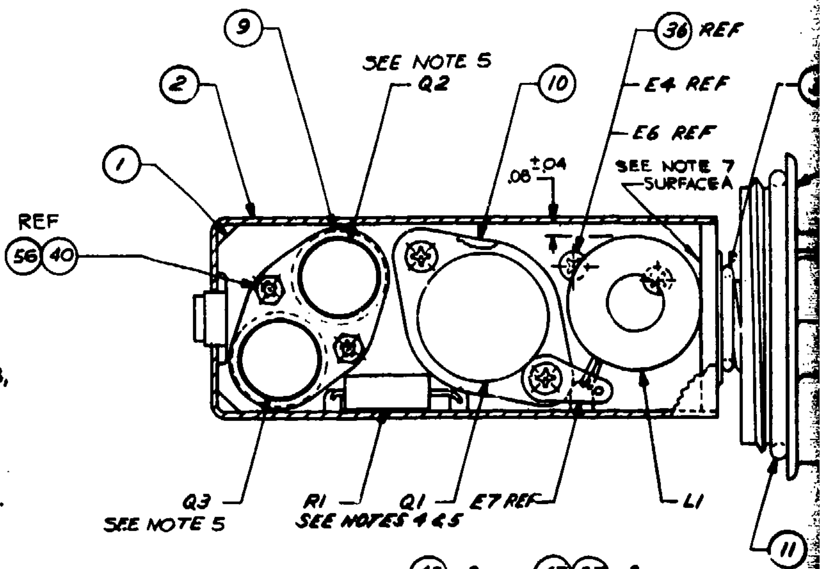
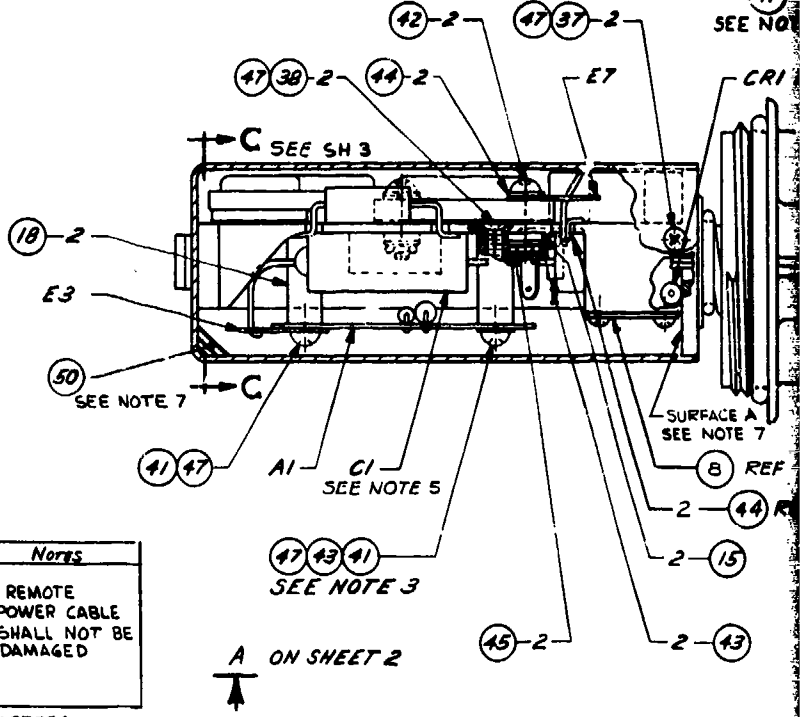
NOTES:

1. WORKMANSHIP SHALL BE IN ACCORDANCE WITH REQUIREMENT 9 OF MIL-STD-454.
2. INSTALL FIND NO 5 ONTO FIND NO.1 UNTIL .220 DIMENSION IS MET THEN BACK OFF UNTIL THREADED HOLE IN SIDE OF FIND NO.5 LINES UP WITH FLAT OF FIND NO.1. INSTALL FIND NO. 54.
3. APPLY A COATING OF FIND NO. 47 TO THREADS OF FIND NOS. 35 THRU 41 PRIOR TO ASSEMBLY.
4. BOND C1, C2, CR1, L1, R1 AND FIND NO.17 TO FIND NO.1 USING FIND NO 49.
5. SLEEVE THE LEADS OF C1, C2, CR1, Q1, Q2, Q3, L1 AND R1 WITH FIND NO. 53.
6. APPLY FIND NO. 48 TO MATING SURFACES OF FIND NOS 1 AND 2 AS SHOWN.
7. PRIME INSIDE SURFACES OF FIND NO. 2 AND SURFACES A OF FIND NO.1 USING FIND NO.50. AFTER ELECTRICAL TEST POT ENTIRE ASSEMBLY USING FIND NO. 50.
8. FILL FIND NOS. 5 AND 6 AND CR1 CAVITY OF FIND NO. 1 WITH FIND NO. 57.
9. INSTALL FIND NO. 60 ON EACH CONDUCTOR OF FIND NO. 52 AS SHOWN. APPLY HEAT AT 150°C (300°F) TO SHRINK. INSTALL FIND NO. 58 AS SHOWN AND APPLY HEAT AT 150°C (300°F) TO SHRINK.
10. HOT STAMP MARKINGS ON FIND NO. 62 USING CONTRASTING COLOR FOIL PER FIND NO. 63. SEE SHEET 3 FOR MARKING INFORMATION.
11. CENTER FIND NOS 64 & 65 ON SURFACE OF FIND NO.2 AS INDICATED.
12. PERFORMANCE CHARACTERISTICS:

INPUT COND	OUTPUT LOAD	OUTPUT VOLTAGE	NOTES
+20VDC TO +23VDC (CONTINUOUSLY)	100MA (CONTINUOUSLY) 1A FOR A DURATION OF 1 SECOND AT A MAX RATE OF 96 PER HOUR	EQUAL TO INPUT VOLTAGE +0 -1.5VDC	
+23VDC TO +40VDC (CONTINUOUSLY)	100 MA (CONTINUOUSLY) 1A FOR A DURATION OF 1 SECOND AT A MAX RATE OF 96 PER HOUR	+22.5 ±1.5VDC	
DC VOLTAGE WITH RIPPLE PER MIL-STD-1275(AT)		RIPPLE ON OUTPUT VOLTAGE SHALL NOT EXCEED 100mv	
100VDC FOR A DURATION OF 50ms DECAYING EXPONENTIALLY TO +40VDC IN 200ms			REMOTE POWER CABLE SHALL NOT BE DAMAGED
0 TO -48 VDC			

13. *MARK THE FOLLOWING IN .09 HIGH STANDARD GOTHIC CHARACTERS, ABBREVIATIONS OPTIONAL, PER MIL-M-13231 USING FIND NO. 66.*
    CABLE ASSEMBLY, SPECIAL PURPOSE, ELECTRICAL CX-13021( ) GVS-5
    PN: 80063 ASSY 952008 MFR: [ ]
    (INSERT CURRENT MANUFACTURER'S CODE IDENT NO.)
14. *SOLDER PER MIL-STD-454, REQT 5, USING FIND NO. 46.*
15. *VENDOR ITEM, SEE SPECIFICATION OR SOURCE CONTROL DRAWING.*
16. *APPLY FIND NO. 67 SPARINGLY TO FIND NO. 11 AND WIPE NEARLY DRY WITH A CLEAN LINTLESS CLOTH*





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2	✓		
3	✓		

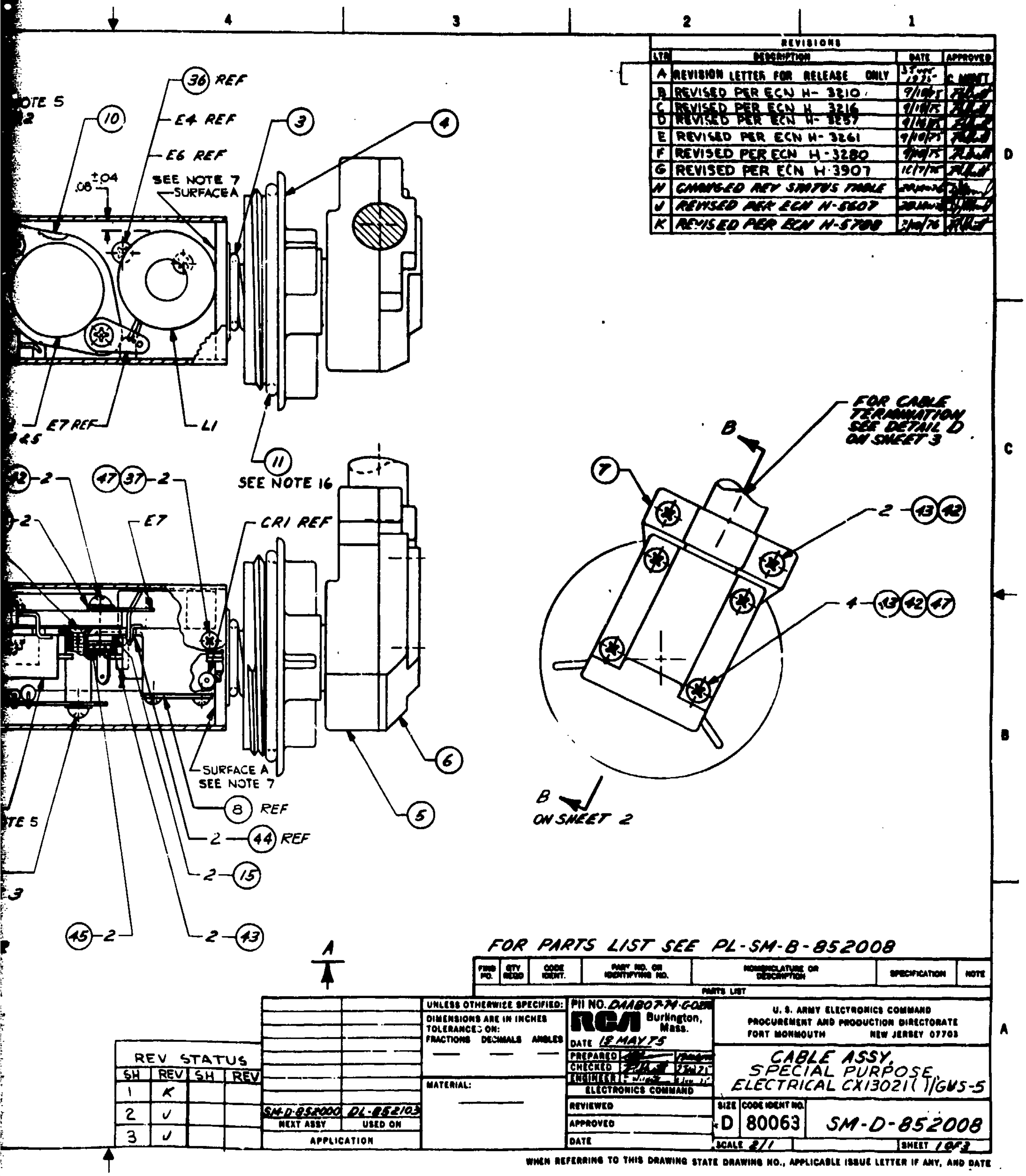

Figure 2-14. Remote Power Cable Configuration (Sheet 1 of 3)

8	7	6	5	4

NOTE
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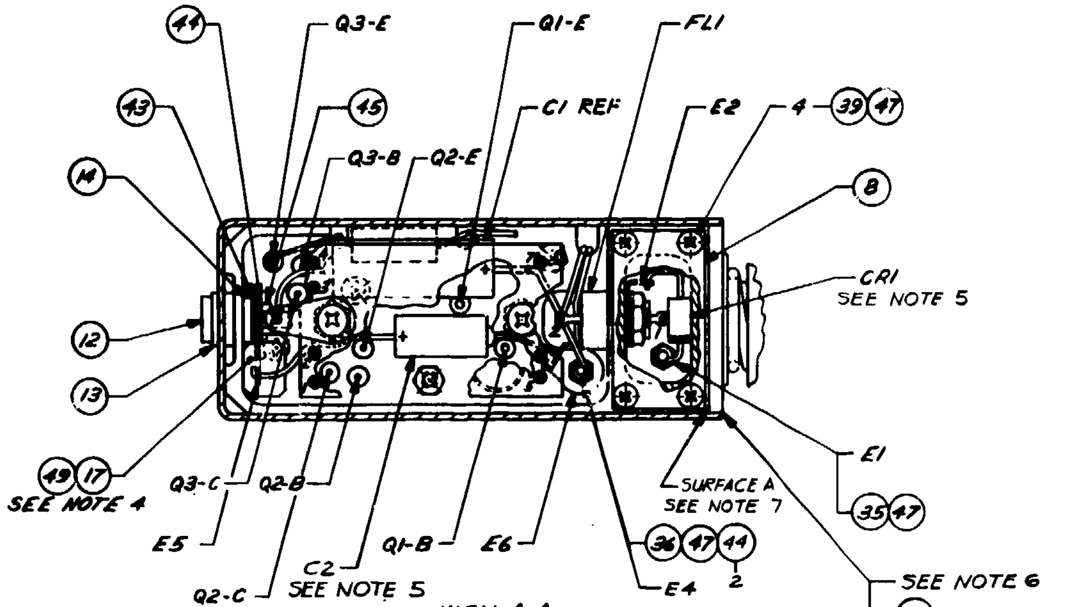
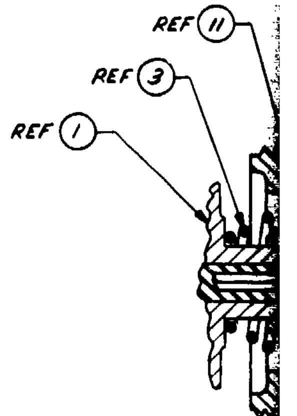
D





C

VIEW A-A
SEE SHEET 1

B

CROSS INDEX OF REF DES TO FIND NO.

REF DES	FIND NO.
A1	19
C1	20
C2	21
CR1	22
E1	23
E2	24
E3	25
E4	26
E5	25
E6	25
E7	25
E8	27
E9	27
FL1	28
L1	29
Q1	30
Q2	31
Q3	31
R1	32

WIRING LEGEND

FROM	TO	FIND NO.	COLOR
E1	E9	52	BLACK
E8	FL1-1		WHITE
E1	E2	CR1	
FL1-2	L1	LEAD OF L1	
L1	E4	LEAD OF L1	
E4	E3	C1	
E4	Q1-E	51	WHITE
E4	A1-7	51	WHITE
Q1-B	Q2-C	51	WHITE
Q1-B	A1-6	51	WHITE
Q2-E	Q3-E	51	WHITE
Q2-B	A1-5	51	WHITE
Q3-E	R1-1	LEAD OF R1	
Q3-C	A1-2	51	WHITE
Q3-B	A1-1	51	WHITE
R1-2	E6	LEAD OF R1	
E6	E5	C2	
E6	A1-3	51	WHITE
E5	E7	51	WHITE
E5	A1-4	51	WHITE

TWISTED PAIR

A

SM-D-
NEXT

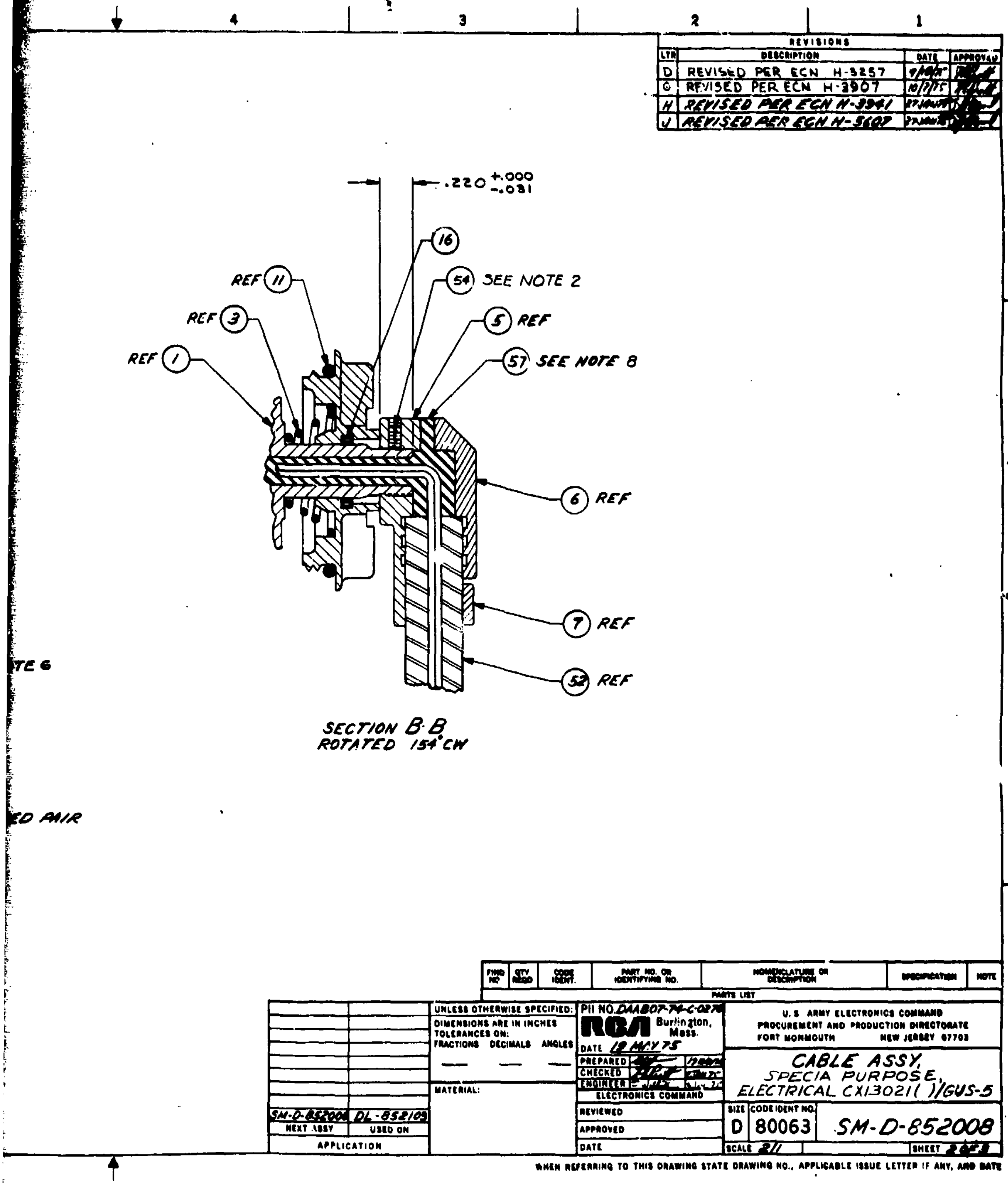


Figure 2-14. Remote Power Cable Configuration (Sheet 2 of 3)

NOTE
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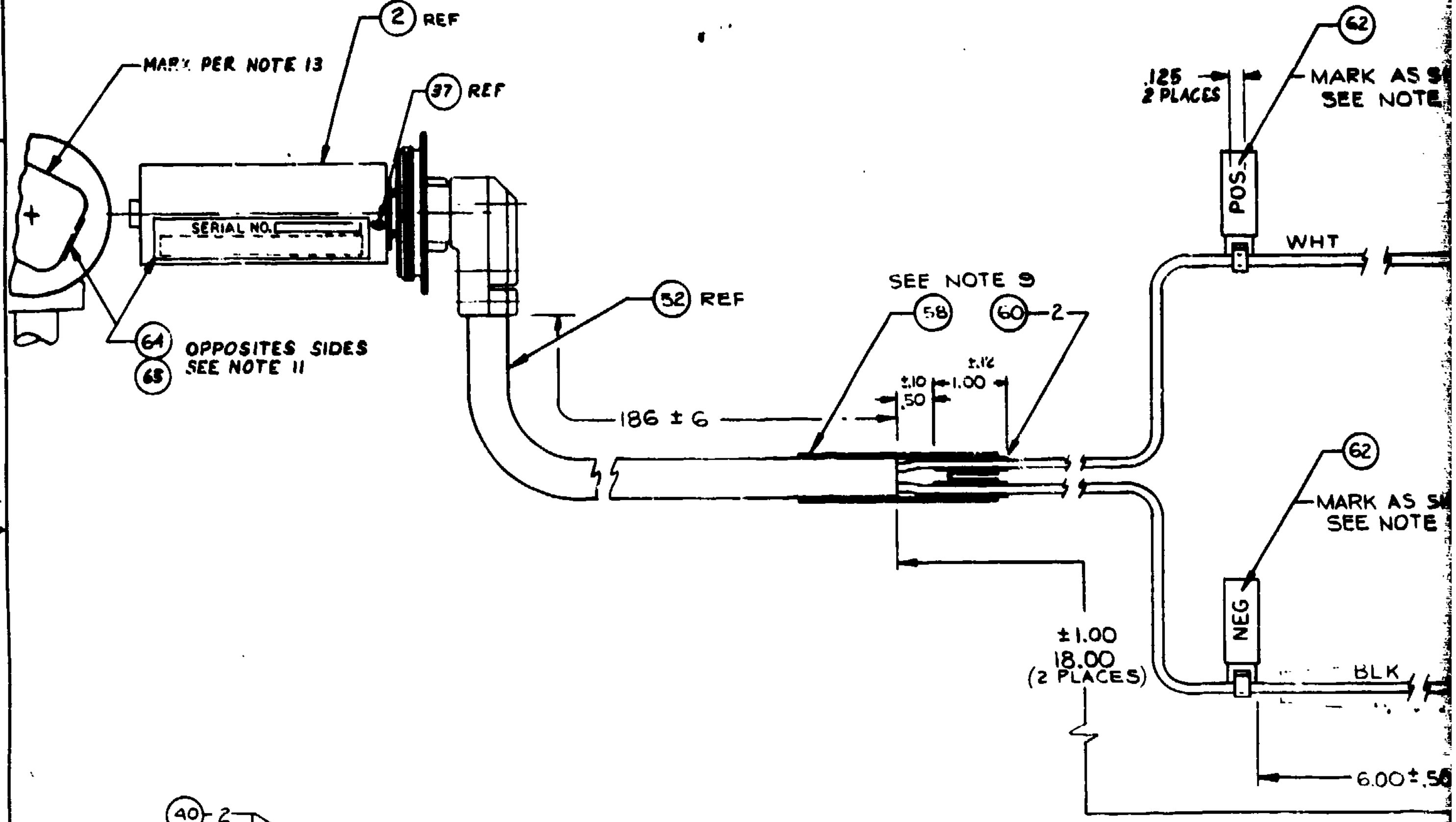
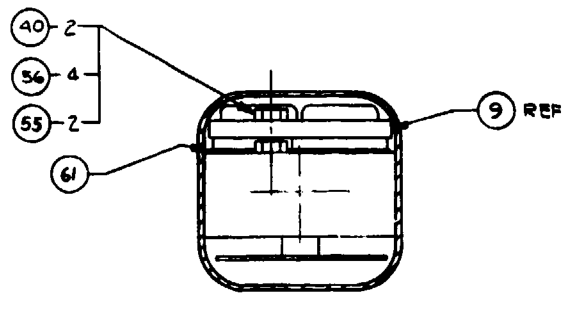


DETAIL D
SCALE: 1/1



SECTION C-C
SEE SHEET 1

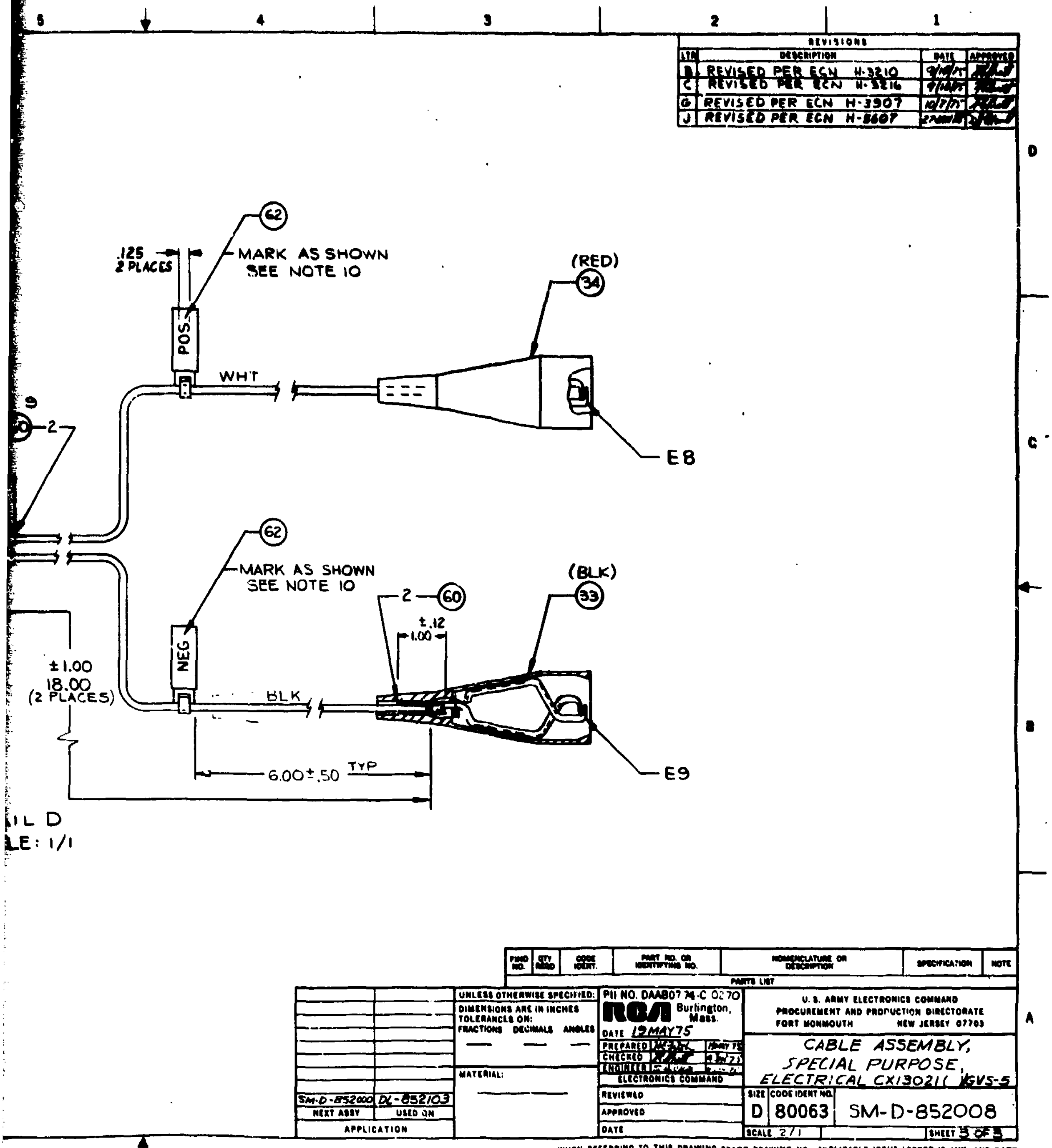
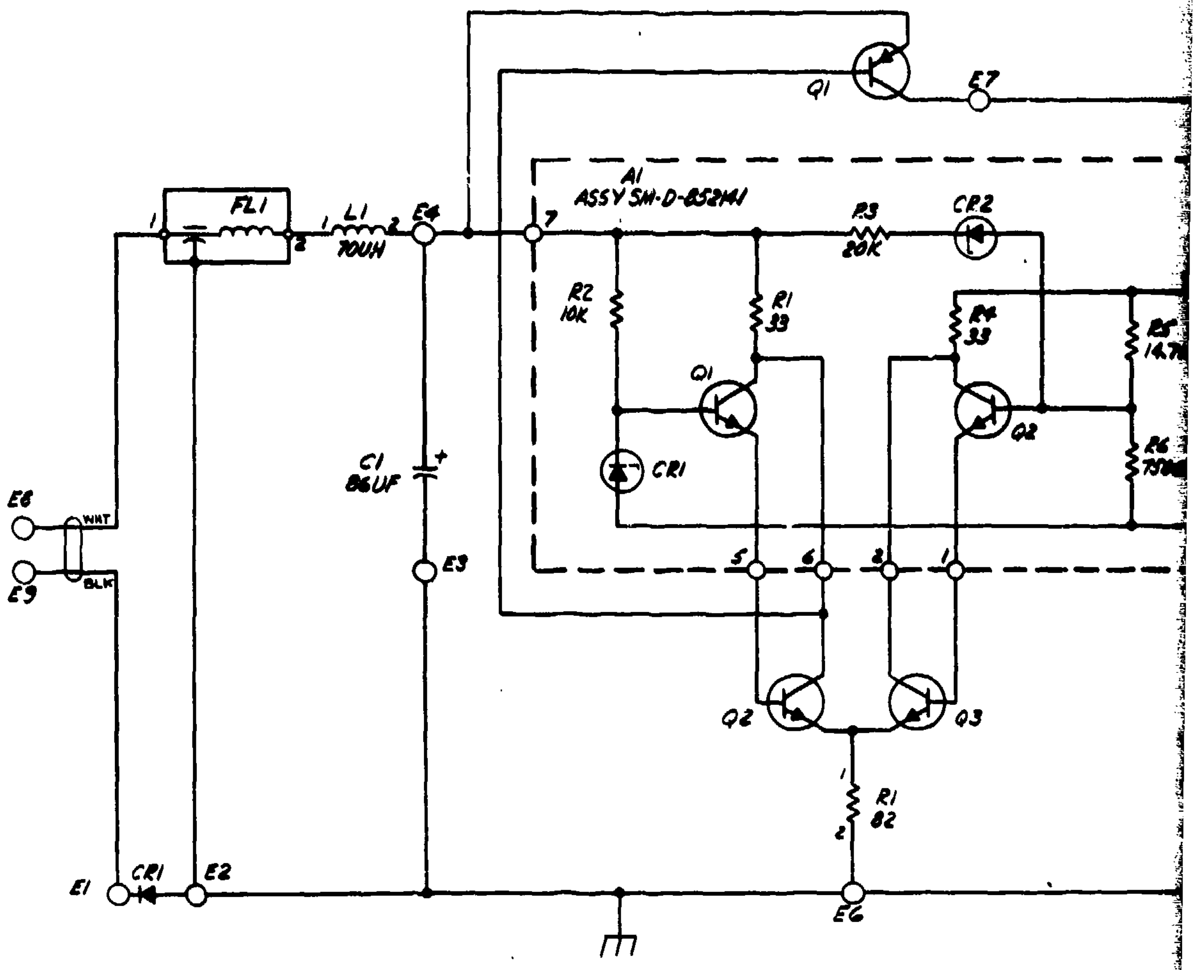
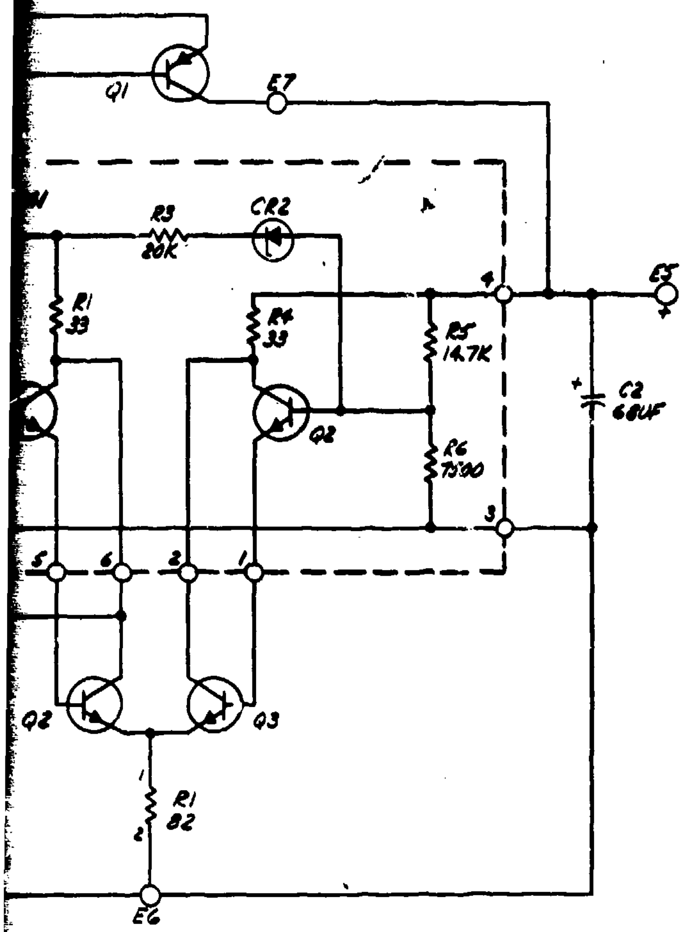


Figure 2-14. Remote Power Cable Configuration (Sheet 3 of 3)

NOTE
DATA MARKED WITH AN ASTERISK (*) IS PECULIAR TO A PRIOR MANUFACTURER. IT DOES NOT TAKE PRECEDENCE OVER ANY OTHER DATA ON THIS DRAWING, AND IS NOT CONTRACTUALLY BINDING ON EITHER THE CONTRACTOR OR THE GOVERNMENT.



NOTES:
1. UNLESS OTHERWISE SPECIFIED;
   RESISTOR VALUES ARE IN OHMS.
2. PARTIAL REFERENCE DESIGNATIONS ARE SHOWN;
   FOR COMPLETE DESIGNATION PREFIX WITH UNIT NO.
   AND SUBASSEMBLY DESIGNATION(S).



REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED
A	REVISION LETTER FOR RELEASE ONLY	75	
B	REVISED PER ECN H-3238	8/27/75	
C	REVISED PER ECN H-3276	9/30/75	
D	REVISED PER ECN H-3903	10/7/75	
E	REVISED PER ECN NO. H8764	2/12/76	

PART NO.	REF DES	VOLT	WATT	TOL ± %
JAN1N756A	A1CR1			
JAN1N973B	A1CR2			
JAN2N3498	A1Q1			
JAN2N2222A	A1Q2			
RCR05G330KM	A1R1		1/8	10
RCR07G103KM	A1R2		1/4	10
RCR07G203KM	A1R3		1/4	10
RCR07G330KM	A1R4		1/4	10
RNC50H1472FM	A1R5	200	1/20	1
RNC50H7501FM	A1R6	200	1/20	1
M39006/09-6187	C1	100		20
M39006/09-1924	C2	30		5
JAN1N5187	CR1			
SM-C-852013	FL1			
SM-C-852040	L1			
SM-C-852271	Q1			
JAN2N1486	Q2,Q3			
RCR32G820KM	R1		1	10

FIND NO. | QTY REQD | CODE IDENT. | PART NO. OR IDENTIFYING NO. | NOMENCLATURE OR DESCRIPTION | SPECIFICATION | NOTE

PARTS LIST

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES TOLERANCES ON: FRACTIONS DECIMALS ANGLES

MATERIAL:

PII NO. DAAB07-74-C-0270

RCA Burlington, Mass.

DATE 13 MAY 75

PREPARED | CHECKED | ENGINEER

ELECTRONICS COMMAND

REVIEWED

APPROVED

DATE

U. S. ARMY ELECTRONICS COMMAND
PROCUREMENT AND PRODUCTION DIRECTORATE
FORT MONMOUTH NEW JERSEY 07703

ELECTRONIC SCHEMATIC DIAGRAM - EXTERNAL POWER CABLE

SIZE	CODE IDENT NO.	
D	80063	SM-D-852142

SCALE — SHEET 1 OF 1

SM-D-852968	DL852143
NEXT ASSY	USED ON
APPLICATION	

WHEN REFERRING TO THIS DRAWING STATE DRAWING NO., APPLICABLE ISSUE LETTER IF ANY, AND DATE

Figure 2-15. Remote Power Cable Electronic Schematic

2.3 TEST SET, LASER RANGEFINDER TS-3620( )/GVS-5 GENERAL PURPOSE AND FUNCTIONS

The special test equipment (STE) described herein is designed to provide a "GO/NO-GO" test function for the LRF and also to act as an optical signal generator and laser output monitor for LRF troubleshooting. The unit is a lightweight, self-contained test set in a combination case.

The STE consists of the following major components:

(1) Test Set
(2) AC Power Cable
(3) LRF Power Adapter Cable
(4) Alignment Bracket

The STE provides the following functions:

(1) A green light if the laser output energy is above a minimum acceptable level, and a red light if the laser output energy is present but below the minimum acceptable level.

(2) A delayed calibrated optical pulse to the LRF corresponding to a range of 4,800 $\pm$ 200 meters to provide a check on the ranging function and receiver sensitivity.

(3) A pair of optical pulses to the LRF separated by a time equivalent to a range separation of 100 $\pm$ 33 meters to test the multiple target detection circuitry.

(4) Either single or paired output optical pulses at a 50 pps rate to facilitate troubleshooting the LRF to the module level. The output power of the single optical pulse is approximately double the output of each pulse of the paired pulses.

(5) An output pulse with amplitude proportional (approximately) to the laser pulse output power of the unit under test.

The STE contains an Alignment Bracket, stowed in the cover, which can be mounted on the mounting stand on the front panel. This bracket carries a captive screw with knurled knob for fastening the LRF in the proper test position and an interlocking arm to override the LRF interlocks when the LRF - with cover removed - is mounted on the STE.

Also, the STE contains a detachable AC input power cord and a DC power cable which fits into the battery compartment of the LRF to provide prime power to the LRF from an external power supply. The cables are stowed in the STE cover.

2.3.1 Packaging Design

2.3.1.1 Combination Case

The STE is packaged in a Zero Manufacturing Company combination carrying/equipment case which is ruggedized to meet the requirements of MIL-T-21200L, Class 3. The overall dimensions of the STE case are shown in Figure 2-16. The case is equipped with an automatic pressure relief valve having an operating range of 3.5 psi vacuum to 2.5 psi pressure and the case cover flange has a combination EMI/moisture gasket.

The protruding items on the case, such as the pressure relief valve, cover latches, and handle are protected by welded flanges from damage during transit, in accordance with the requirements of MIL-T-21200L.

The STE cover is hinged at the rear of the case with the hinges designed so that the cover is readily removable. The inside of the cover has been modified to include two storage compartments. One storage compartment is used to store the AC power cable; the other, is used to store the AN/GVS-5 adapter cable assembly. The inside surfaces of both storage compartments are lined with closed cell silicone sponge rubber to protect the stored equipment from damage during transit. The cover for the AC power cable storage compartment has two threaded bosses which are used to store the optical alignment bracket when it is not in use (see Figure 2-17).

The control panel, optics, and electronics are all packaged in the lower half of the case as shown in Figure 2-18.

The total weight of the STE is approximately 30 pounds.

8	7	6	5	4

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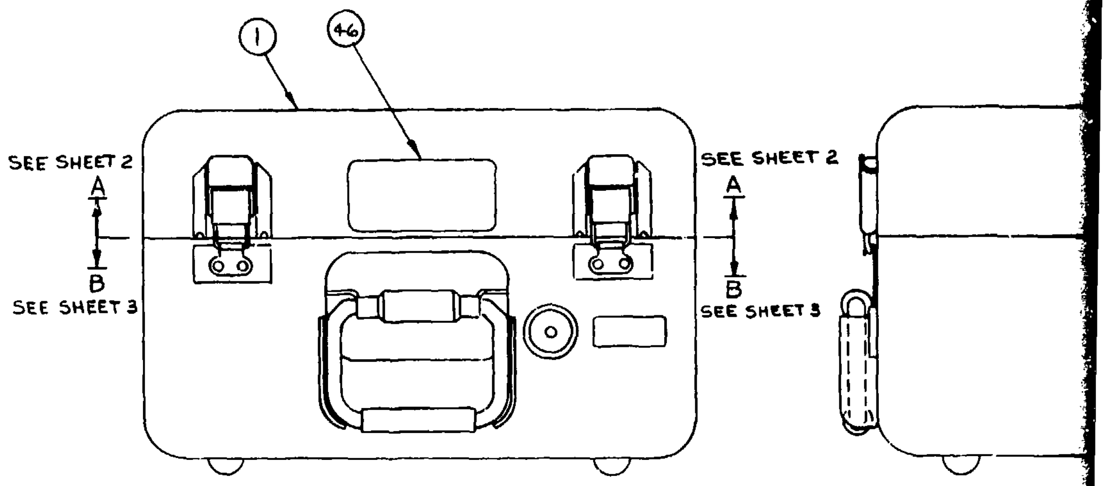
D



C

NOTES:
1. WORKMANSHIP SHALL BE IN ACCORDANCE WITH MIL-STD-454 REQT 9.
2. FOR ELECTRICAL SCHEMATIC SEE SM-D-852372.
3. SOLDER PER MIL-STD-454 REQT 5 USING ITEM 47.
4. VENDOR ITEM, SEE SPECIFICATION OR SOURCE CONTROL DRAWING.
5. TEST IN ACCORDANCE WITH SM-A-852450.
6. MARK SERIAL NO. WITH .12 HIGH GOTHIC CHARACTERS USING ITEM 68 LOCATED APPROX AS SHOWN.

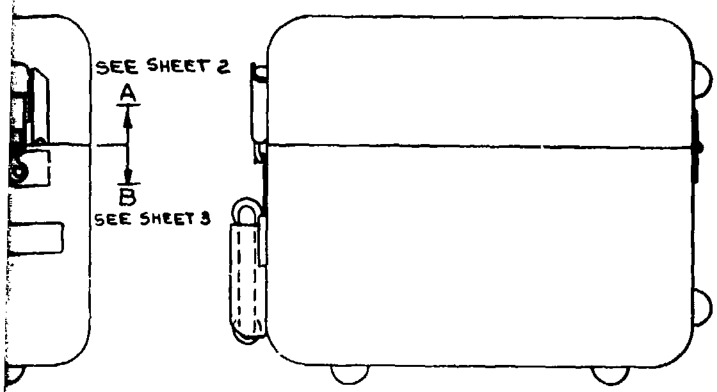
B

A

SHT	REV
4	C
3	C
2	C
1	C

REV STATUS

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED
A	REVISION LETTER FOR RELEASE ONLY		
B	REVISED PER ECN H-4030		
C	REVISED PER ECN H 6517		



...H MIL-STD-454 REQT 9.
...2.
...7.
...E CONTROL DRAWING.
...ERS USING ITEM 68

FOR PARTS LIST SEE PL-SM-B-852360

FIND NO.	QTY REQD	CODE IDENT	PART NO. OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	SPECIFICATION	NOTE

PARTS LIST

ShT	REV
4	C
3	C
2	C
1	C

REV STATUS

NEXT ASSY	USED ON

APPLICATION

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES ON:
FRACTIONS DECIMALS ANGLES

MATERIAL:

PII NO. DAAB07-74-C-0270
RCA Burlington, Mass.
DATE 15 OCT 1975
PREPARED
CHECKED
ENGINEER
ELECTRONICS COMMAND
REVIEWED
APPROVED
DATE

U. S. ARMY ELECTRONICS COMMAND
PROCUREMENT AND PRODUCTION DIRECTORATE
FORT MONMOUTH NEW JERSEY 07703

TEST SET ASSEMBLY
TS-3620( )/GVS-5 (V)

SIZE	CODE IDENT NO.	
D	80063	SM-D-852360

SCALE 1/2 SHEET 1 OF 4

WHEN REFERRING TO THIS DRAWING STATE DRAWING NO., APPLICABLE ISSUE LETTER IF ANY, AND DATE

Figure 2-16. STE Carrying Case Dimensions

8	7	6	5	4

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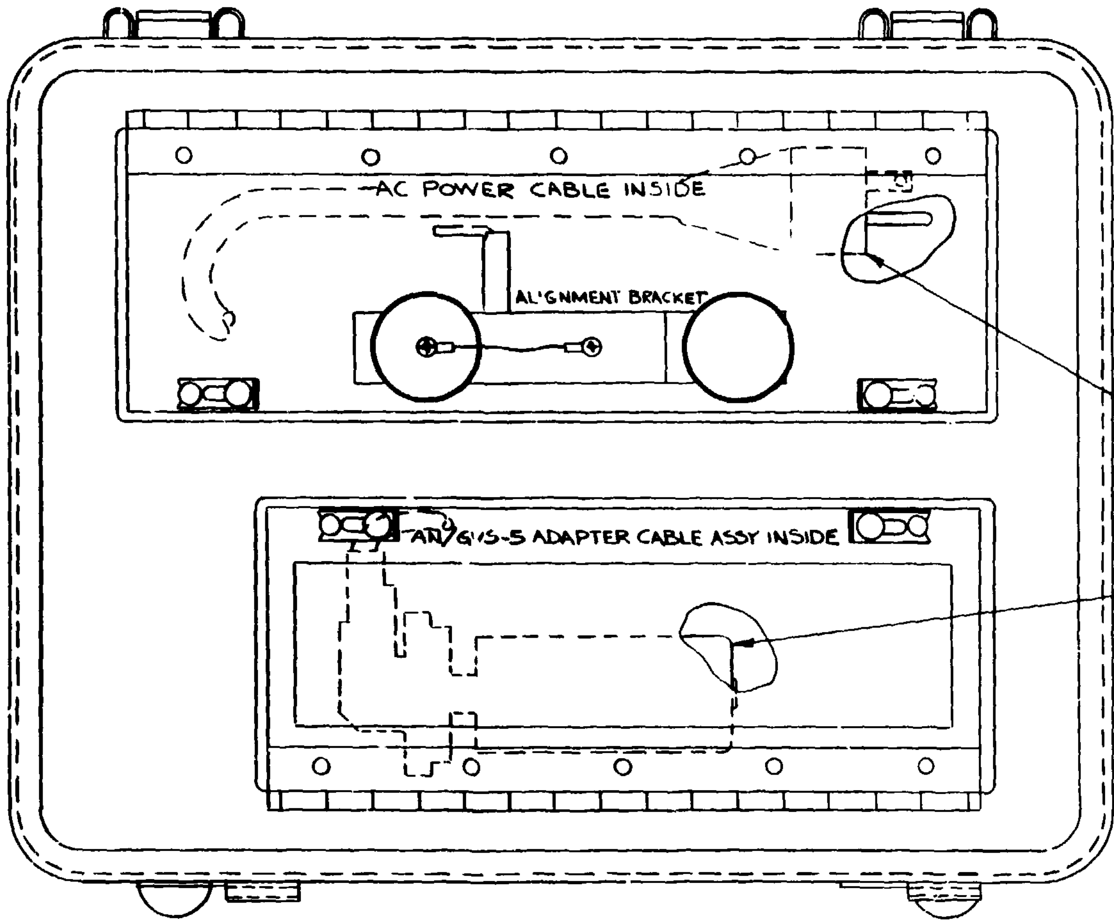

VIEW A-A
COVER DETACHED

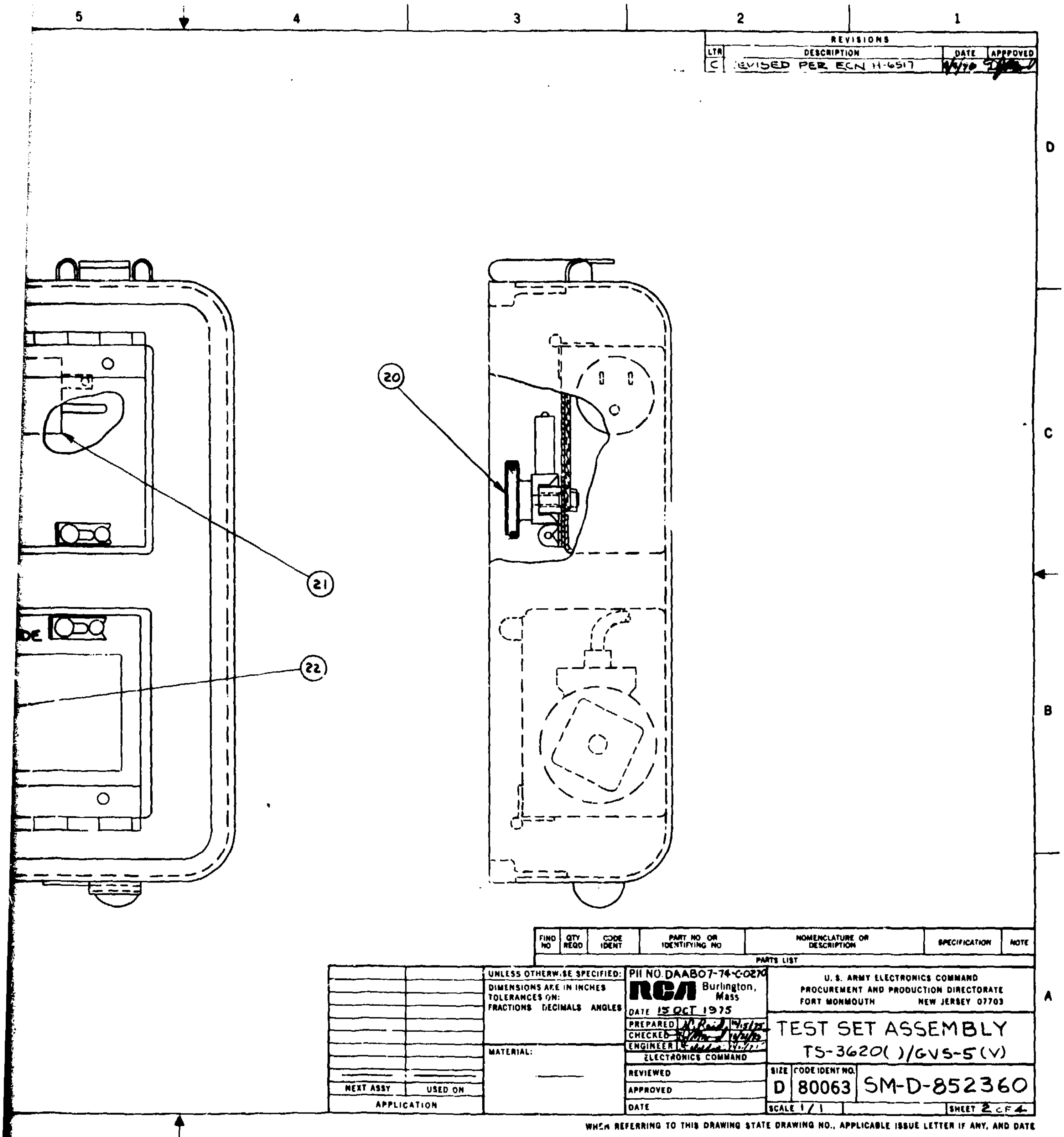

Figure 2-17. STE Carrying Case Cover Storage Compartments

8 7 6 5 4

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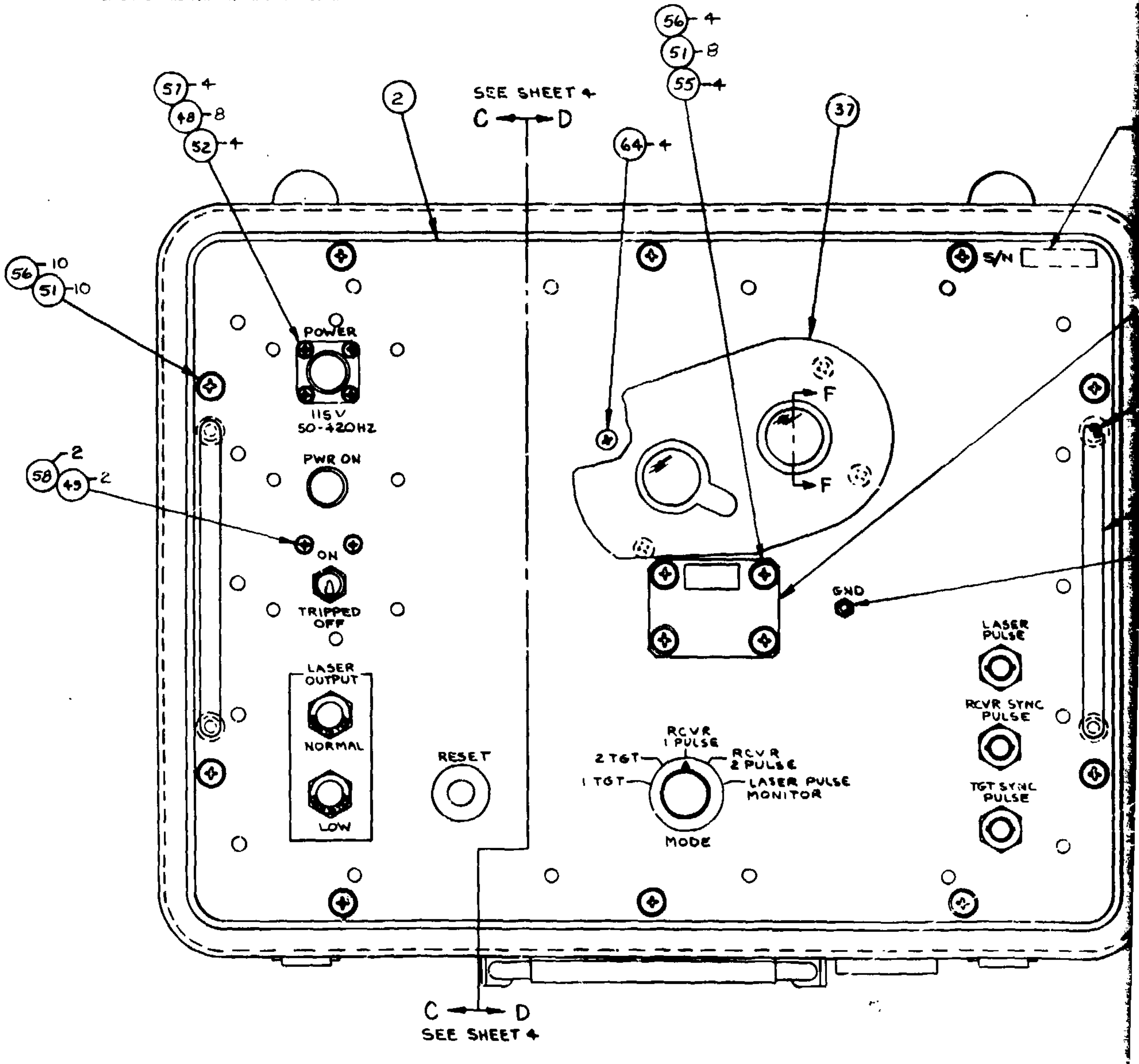
D

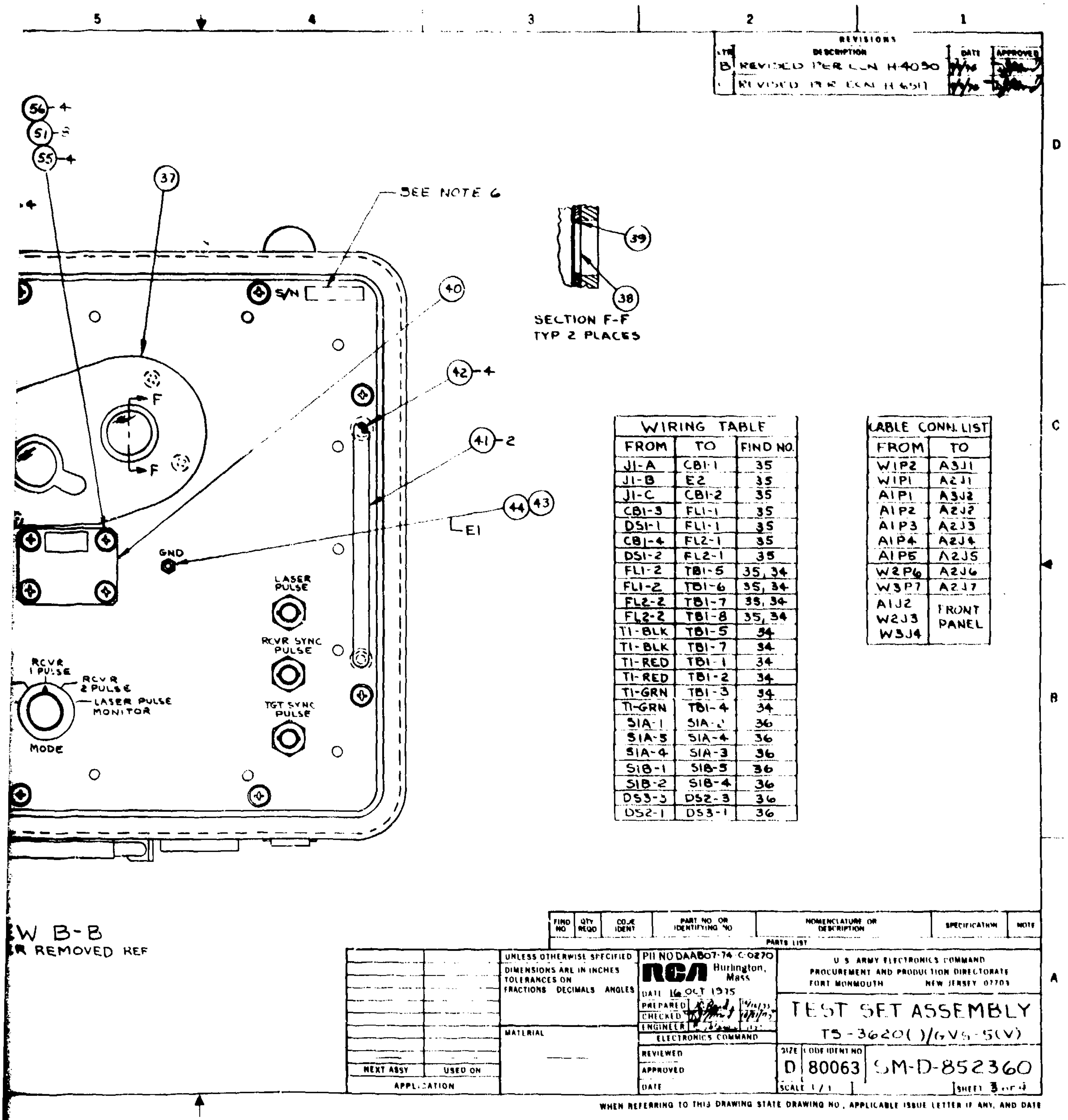
C

B

A



VIEW B-B
COVER REMOVED REF



WIRING TABLE

FROM	TO	FIND NO.
J1-A	CB1-1	35
J1-B	E2	35
J1-C	CB1-2	35
CB1-3	FL1-1	35
DS1-1	FL1-1	35
CB1-4	FL2-1	35
DS1-2	FL2-1	35
FL1-2	TB1-5	35, 34
FL1-2	TB1-6	35, 34
FL2-2	TB1-7	35, 34
FL2-2	TB1-8	35, 34
T1-BLK	TB1-5	34
T1-BLK	TB1-7	34
T1-RED	TB1-1	34
T1-RED	TB1-2	34
T1-GRN	TB1-3	34
T1-GRN	TB1-4	34
S1A-1	S1A-2	36
S1A-5	S1A-4	36
S1A-4	S1A-3	36
S1B-1	S1B-5	36
S1B-2	S1B-4	36
DS3-3	DS2-3	36
DS2-1	DS3-1	36

CABLE CONN. LIST

FROM	TO
W1P2	A3J1
W1P1	A2J1
A1P1	A3J2
A1P2	A2J2
A1P3	A2J3
A1P4	A2J4
A1P5	A2J5
W2P6	A2J6
W3P7	A2J7
A1J2 W2J3 W3J4	FRONT PANEL

Figure 2-18. STE Control Panel, Optics, and Electronics (sheet 1 of 2)

NOTE
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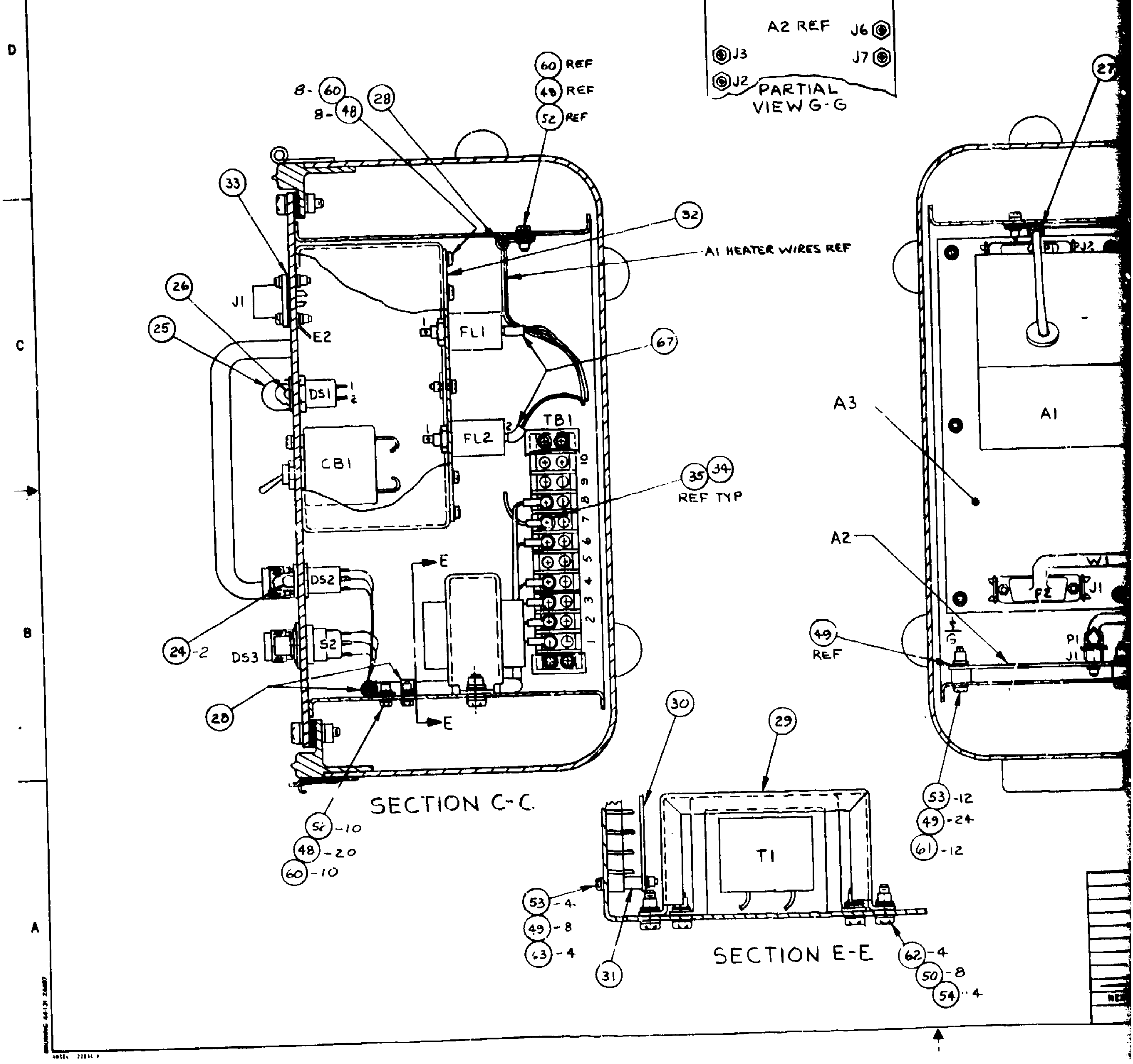

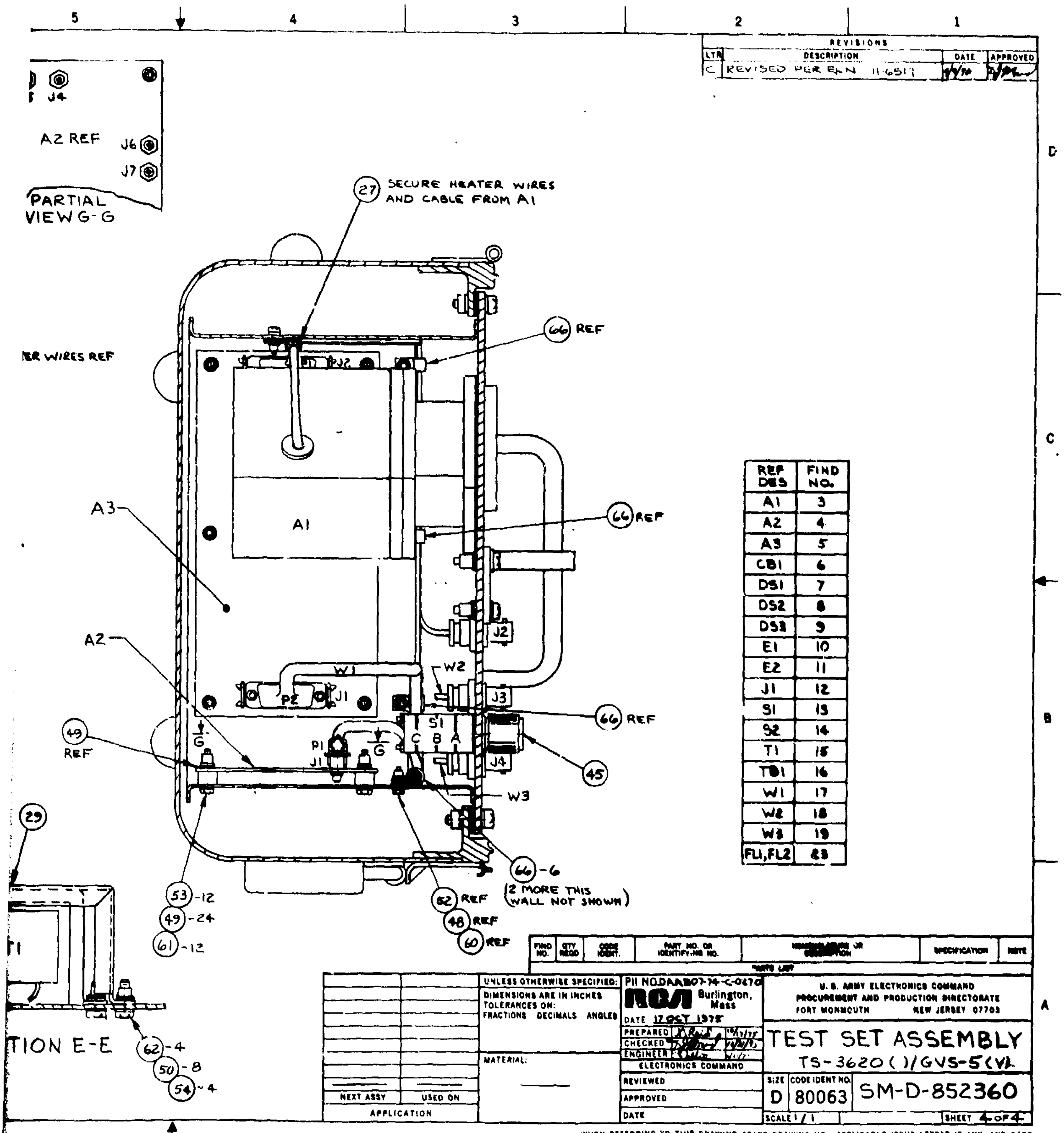

REF DES	FIND NO.
A1	3
A2	4
A3	5
CB1	6
DS1	7
DS2	8
DS3	9
E1	10
E2	11
J1	12
S1	13
S2	14
T1	15
TB1	16
W1	17
W2	18
W3	19
FL1,FL2	23

Figure 2-18. STE Control Panel, Optics, and Electronics (sheet 2 of 2)

2.3.1.2 Control Panel

The STE control panel is fabricated from 0.12 thick 6061-T6 aluminum alloy. The panel is 13.9 inches wide and 10.44 inches high. It has a black anodize finish with clear-aluminum etched nomenclature and characters.

A sheetmetal wrap-around base and filter box chassis are riveted to the control panel forming the chassis assembly shown in Figure 2-19. The STE optics and electronics are all packaged in this chassis assembly. This design feature was incorporated to facilitate wiring, troubleshooting, and maintenance. The STE can, therefore, be operated while removed from the combination case. The sheetmetal wrap-around base performs two functions. First, it is used as a mounting surface for the printed wiring subassemblies and terminal boards; second, the base also protects the optics and electronics during bench handling when the chassis assembly is outside of the combination case.

The layout of the control panel was based on good human engineering design practice and resulted in the locations of the switches, indicator lights, and connectors seen in Figure 2-18.

Removal of the control panel from the combination case is accomplished by removing ten #10-32 screws from the panel and, using the two handles, lifting the panel away from the case.

Also located on the control panel are the optical shroud and the mounting post for the optical alignment bracket. The optical shroud is a low durometer rubber used to provide a light-tight interface between the LRS and STE optics during testing.

2.3.1.2.1 Controls and Connectors

The locations of the controls and connectors, as previously stated, are shown in Figure 2-18. The controls consist of an off-on switch, a mode selector switch, and a reset button. The connectors on the panel, as shown in the figure, are labeled as to their function.

2.3.1.2.2 HHLR Mounting Bracket

The HHLR Mounting Bracket is used to support the HHLR during GO/NO-GO testing of the HHLR. This bracket assembly has been designed to provide optical alignment between the HHLR receiver/transmitter optics and the STE optical assembly.

The alignment bracket, shown in Figure 2-20, is a brazed assembly. The main support post is fabricated from microwave waveguide tubing because of the tight tolerances required for optical alignment. The bracket assembly has two captive, threaded knobs. The lower knob is used to captivate the alignment bracket to the bracket mounting post located on the control panel. Both the bracket and post are keyed to prevent mounting the bracket in the wrong position. The alignment bracket has a hard anodic coat to minimize wear since the bracket is repeatedly mounted to, and removed from, the control panel. The upper knob on the bracket is located at the V-groove end of the bracket and is used to mount the HHLR. The bracket is designed to permit test of the HHLR with the HHLR cover either on or off. The upper knob, therefore, is mounted through a slotted hole. The slotted hole provides the required vertical adjustment required for the difference in HHLR length with cover removed. The alignment bracket has a spring-arm which is used to close the HHLR safety interlock microswitch for testing with the cover removed. This is accomplished by moving the spring-loaded arm towards the HHLR until the arm engages its horizontal detent groove. In this position, the arm depresses the microswitch actuator. The spring-loaded arm is maintained in its stowed vertical position whenever a HHLR is being tested with its cover on.

2.3.1.2.3 Optical Ports

The receiver/transmitter windows located on the STE control panel are the same as the transmitter window which is used on the HHLR. The windows are designed to have a minimum transmission of 90% at 10,648Å. The windows are bonded in place to the control panel.

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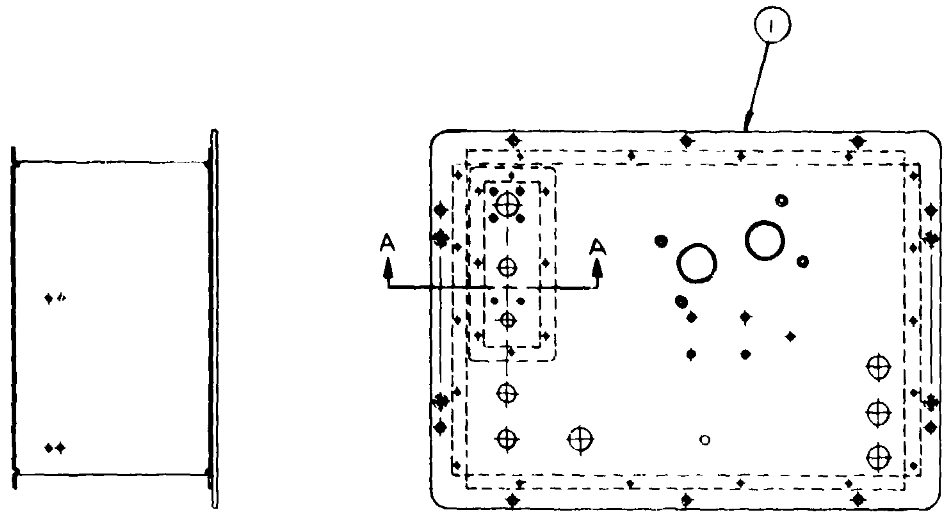

NOTES:

1. WORKMANSHIP SHALL BE IN ACCORDANCE WITH MIL-STD-454, REQT 9.
2. IDENTIFY PER MIL-STD-130.
3. RIVET IN ACCORDANCE WITH NAS523. TOUCH UP INSTALLATION HOLE FOR ITEM 4 USING CHEM FILM PER ITEM 7. AFTER RIVETING ITEM 4 PAINT HEAD TO MATCH PANEL USING BLACK EPOXY-POLYAMIDE PER ITEM 8, COLOR 37038 PER FED-STD-595.

BB = MS20426	BJ = MS20470
BASIC CODE	DASH NO FOR D.A N = MFG NO NEAR SIDE F = MFG NO FAR SIDE
D = DIMPLE FIGURE = NO OF SHTS TO BE DIMPLED C = CSK	DASH NO FOR LENGTH W = SPOTWELD OPTIONAL
NAS 523 RIVET CODE	

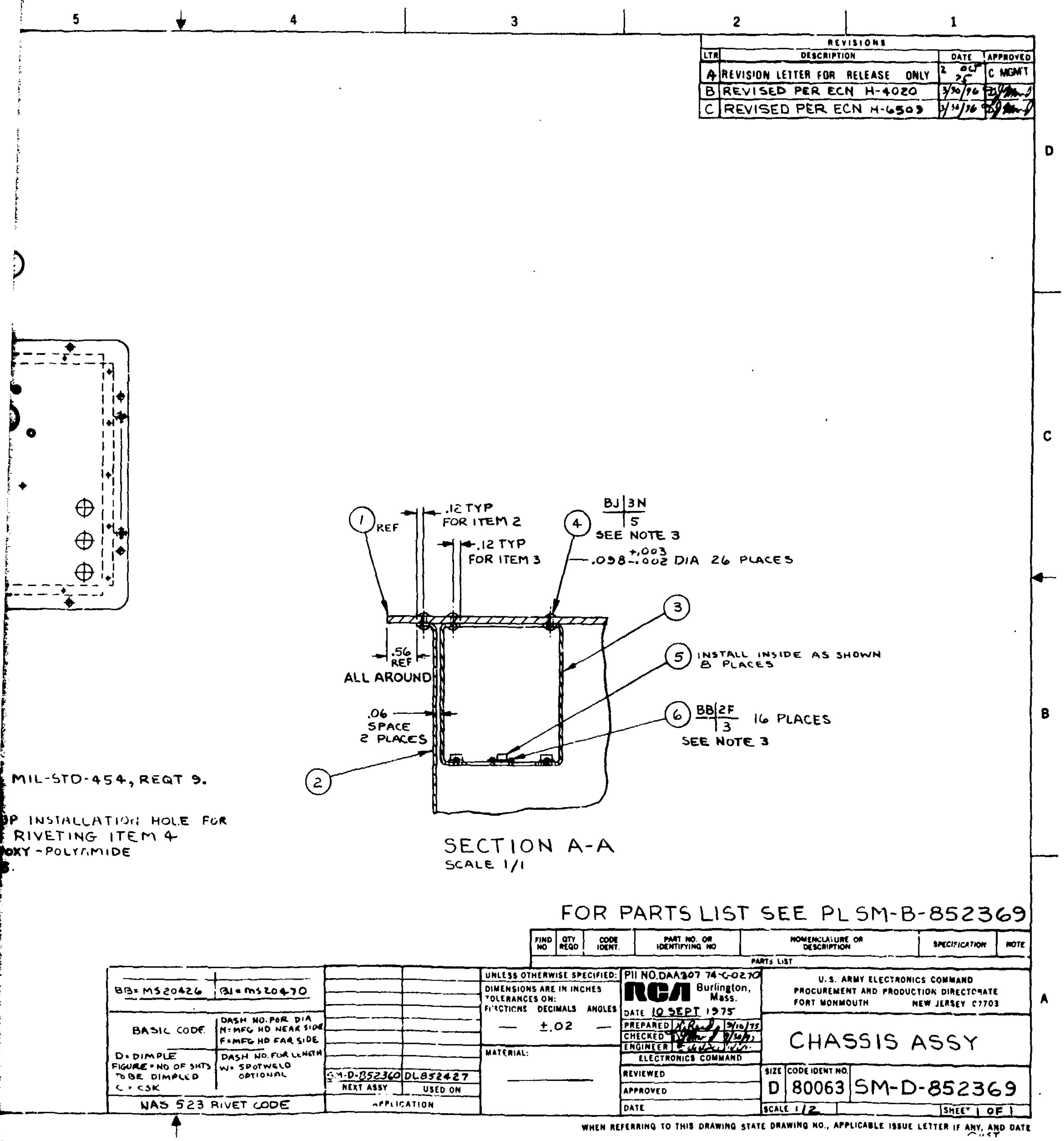

Figure 2-19. STE Control Panel Chassis Assembly

8 7 6 5 4

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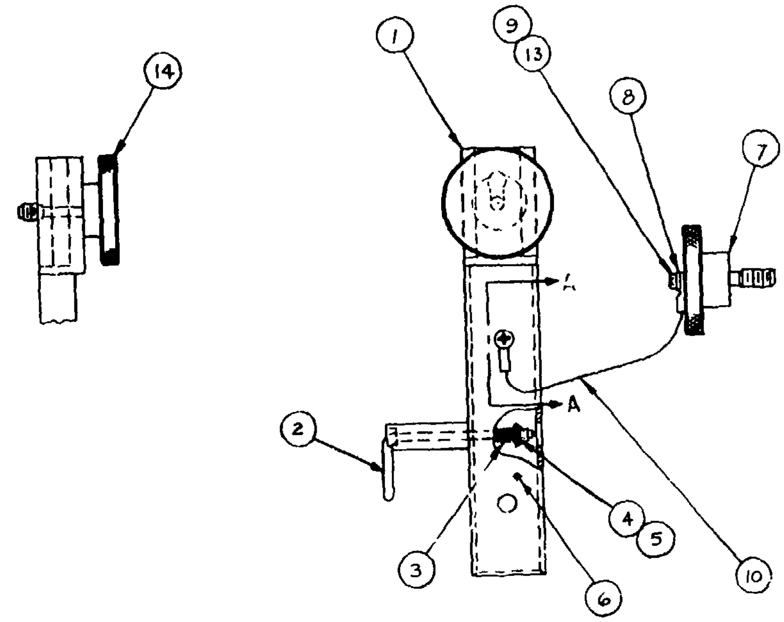

B

NOTES:
1. WORKMANSHIP SHALL BE IN ACCORDANCE WITH MIL-STD-454, REQT 9.
2. APPLY ITEM 13 TO THREADS OF ITEM 9 BEFORE ASSEMBLING TO ITEM 7.
3. IDENTIFY PER MIL-STD-130.

A

SM-D
NEXT

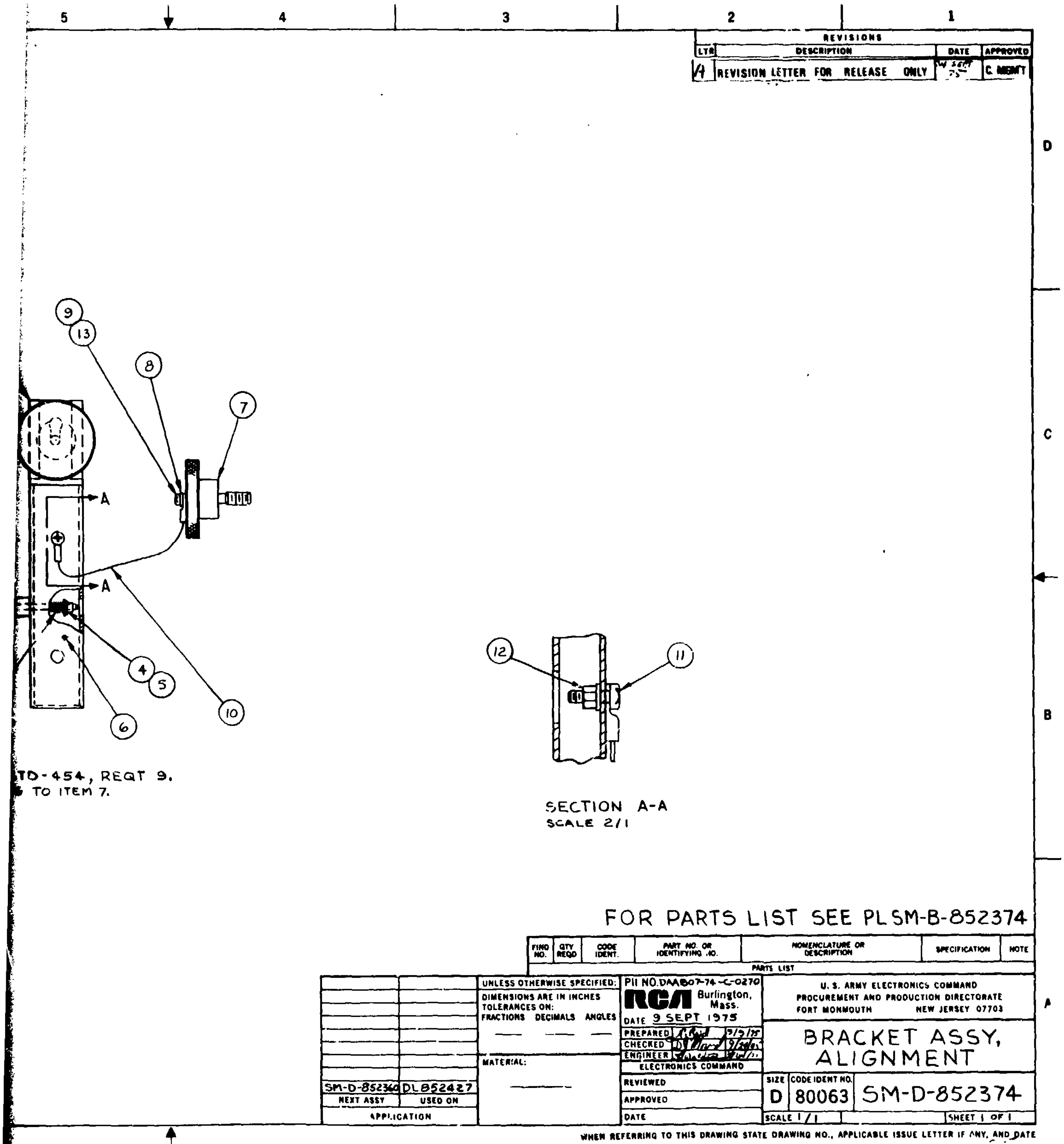

Figure 2-20. STE Alignment Bracket Assembly

2.3.1.3 Oven Assembly

The Oven Assembly is used to maintain the STE receiver/transmitter assembly at 60 $\pm$ 2°C while the STE is operating within an ambient temperature range of 0°C to 55°C. The oven assembly is shown in Figure 2-21.

The Oven Assembly is mounted to the STE optical housing which, in turn, is mounted to the inside surface of the control panel. The receiver/transmitter printed wiring assembly is flange-mounted to the inside of the oven as shown in Figure 2-22.

The inner oven compartment is 4.0 inches long, 1.25 inches wide and 1.62 inches deep and is fabricated from plated copper to promote thermal spreading. The outside surface of this inner compartment is wrapped with a heating wire coil near which is located a temperature sensor. The entire outer surface of the inner compartment is covered with an insulation material. The inner compartment is then mounted into an outside housing. A glass epoxy spacer is used to thermally de-couple the inner oven compartment from its outside housing. The oven control electronics are located at the base of the inner compartment in the space between the inner compartment and the outside shell of the oven. The wiring for the receiver/transmitter printed wiring assembly enters the oven cavity through two grommets in the oven side wall.

2.3.1.3.1 Electronics

The STE electronics are packaged on a 6 x 3.5 inch printed wiring board as shown in Figure 2-23. This board is mounted to the chassis wrap-around base as shown in Figure 2-18.

Electrical interface with the board is via a connector located at the bottom of the board. Following assembly and electrical testing the board is conformally coated with a urethane compound for moisture protection. The larger components on this board are secured to the board with wire for structural integrity under the shock and vibration environment specified. The board is an easily replaced item in the event of a failure. Replacement is accomplished by disconnecting the mating connector from the board connector and removing the six board mounting screws.

2.3.1.4 Power Supply

The STE Power Supply is packaged as a printed wiring assembly mounted on standoffs located on the chassis wrap-around base. The power supply transformer is mounted similarly on the same base, as shown in Figure 2-18.

Due to the weight of the transformer a sheetmetal bracket is used to clamp the transformer in place in addition to its own mounting hardware.

The power supply printed wiring board, shown in Figure 2-24, is 7.0 inches long and 3.5 inches high. The only component on the power supply board requiring a heat sink is the +5V dc regulator microcircuit and this device is mounted on a free convective heat sink. Electrical interfaces to and from the power supply board are via connectors at each end of the board.

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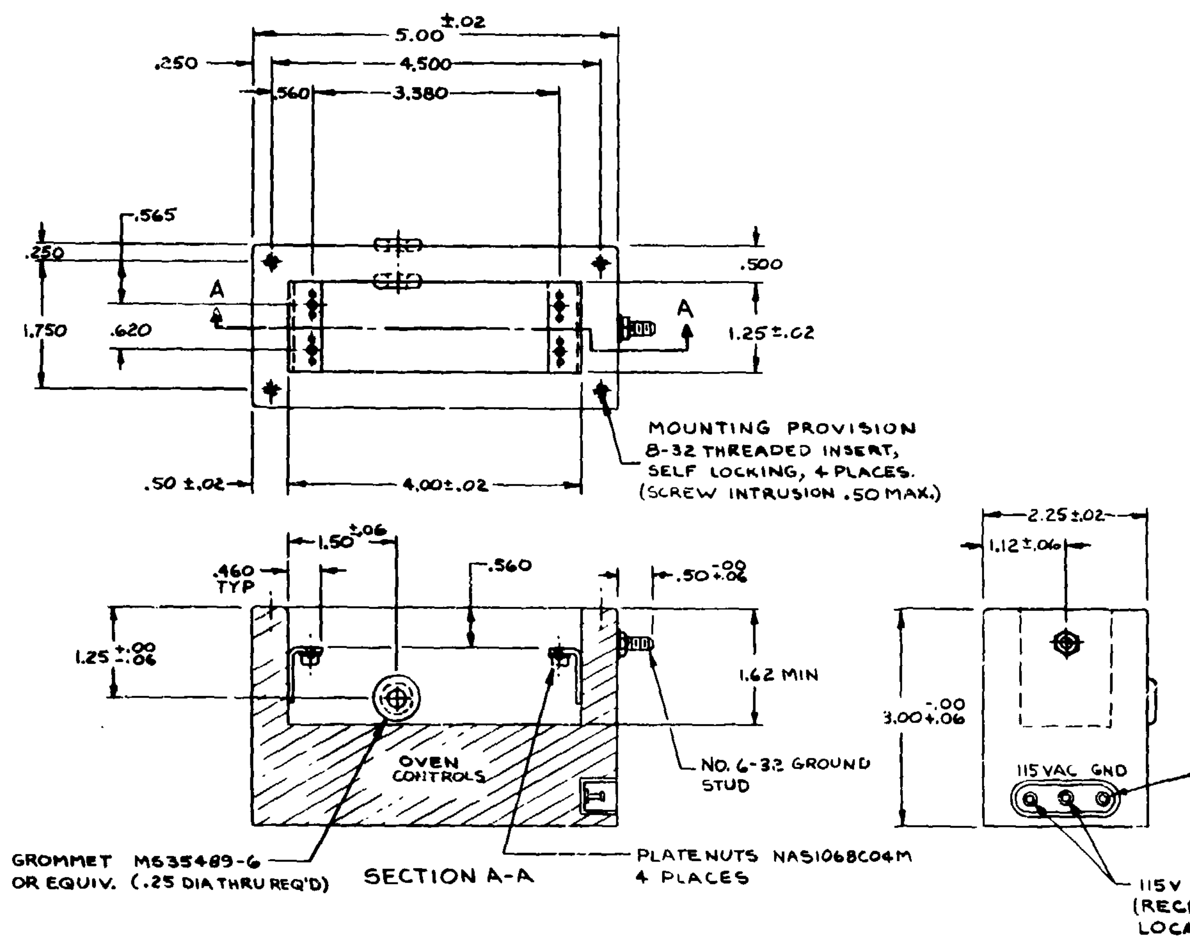


PREPARED IN ACCOR

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED
A	REV LETTER FOR RELEASE ONLY	19 Aug 75	C. [illegible]
B	REVISED PER ECN H-4000	[illegible] 75	[illegible]
C	REVISED PER ECN H-6523	[illegible]/76	[illegible]

NOTES:

1. SOURCE OF SUPPLY

   OVENAIRE, INC   CODE IDENT 12020
   706 FOREST STREET
   CHARLOTTESVILLE, VA 22901

   MANUFACTURERS PART NUMBER 5385-1

   SOURCE INFORMATION IS FOR THE CONVENIENCE OF THE PROCURING ACTIVITY. IT IS NOT TO BE CONSTRUED AS RESTRICTING THE SOURCE OF SUPPLY.

2. PARTS, MATERIALS, AND PROCESSES SHALL BE IN ACCORDANCE WITH MIL-P-11268.

3. THE OVEN SHALL COMPLY WITH THE REQUIREMENTS OF MIL-T-21200 FOR CLASS 3 EQUIPMENT, EXCEPT FOR PARTS, MATERIALS AND PROCESSES.

4. INPUT POWER

4.1 VOLTAGE: 115 V_{RMS} $\pm$10%, SINGLE PHASE AC, 50 TO 420 Hz.

4.2 CURRENT: 260 MA_{RMS} MAXIMUM.

5. TEMPERATURE

5.1 CAVITY: 60°C $\pm$ 2°C AFTER A WARM UP PERIOD OF 15 MINUTES MAXIMUM.

5.2 STABILITY: $\pm$ 1°C OVER THE AMBIENT TEMPERATURE RANGE, WHEN A COVER OF 0.25 IN. THICK EPOXY FIBERGLASS IS FIRMLY ATTACHED TO THE MOUNTING HOLES.

5.3 AMBIENT: 0°C TO +55°C

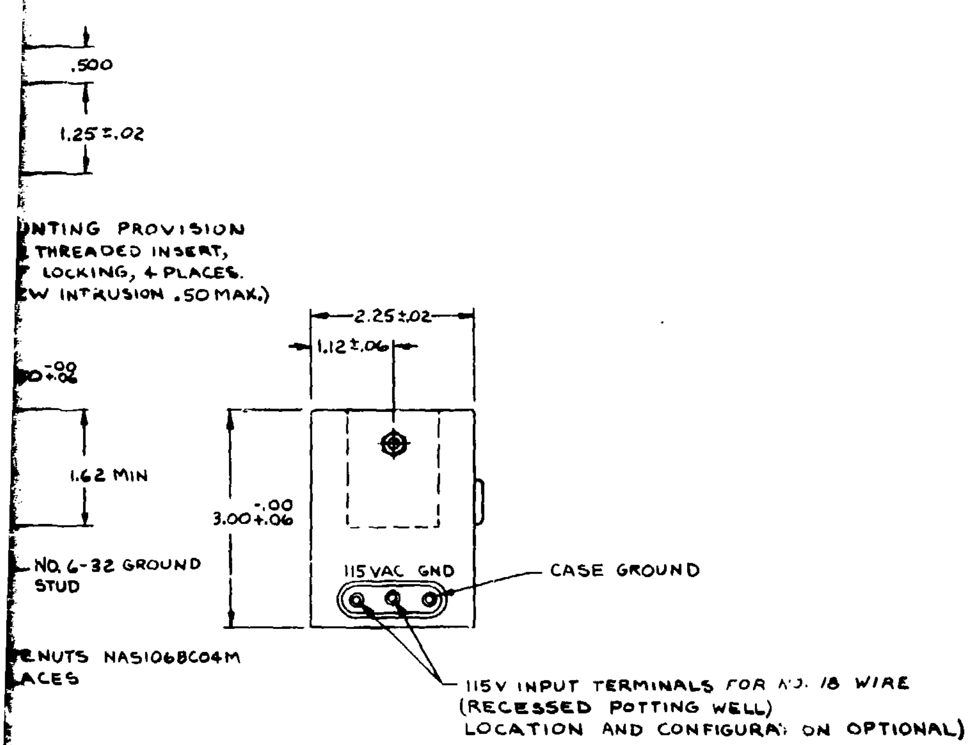
5.4 STORAGE: -60°C TO +72°C

6. EMI: THE OVEN SHALL BE DESIGNED TO COMPLY WITH MIL-STD-461A NOTICE 4 TESTS CE02, RE02, CS02, CS06, AND RS03.1.

7. FINISH: PRIME PER MIL-P-8585. PAINT SEMI-GLOSS BLACK ENAMEL COLOR NO. 27038 PER FED-STD-595 USING PAINT PER TT-E-529.

8. IDENTIFY IN ACCORDANCE WITH MIL-STD-130.

9. WORKMANSHIP SHALL BE IN ACCORDANCE WITH MIL-STD-454 REQUIREMENT 9.



SPECIFICATION CONTROL DRAWING

PREPARED IN ACCORDANCE WITH MIL-STD-100A

FIND NO.	QTY REQD	CODE IDENT.	PART NO. OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	SPECIFICATION	NOTE

PARTS LIST

NEXT ASSY	SM-D-852361
USED ON	DL852432

APPLICATION

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DIMENSIONS ARE IN INCHES
TOLERANCES ON:
FRACTIONS DECIMALS ANGLES
±.010

MATERIAL: —

PII NO. DAAB07-74-C-0270
RCA Burlington, Mass.
DATE 8 AUG 1975
PREPARED [illegible] 8/8/75
CHECKED [illegible]
ENGINEER [illegible]
ELECTRONICS COMMAND
REVIEWED
APPROVED
DATE

U. S. ARMY ELECTRONICS COMMAND
PROCUREMENT AND PRODUCTION DIRECTORATE
FORT MONMOUTH NEW JERSEY 07703

OVEN, TEMPERATURE CONTROLLED

SIZE D | CODE IDENT NO. 80063 | SM-D-852350

SCALE 1/1 | SHEET 1 OF 1

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Figure 2-21. STE Temperature Controlled Oven Assembly

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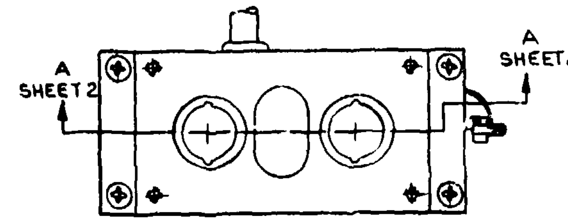

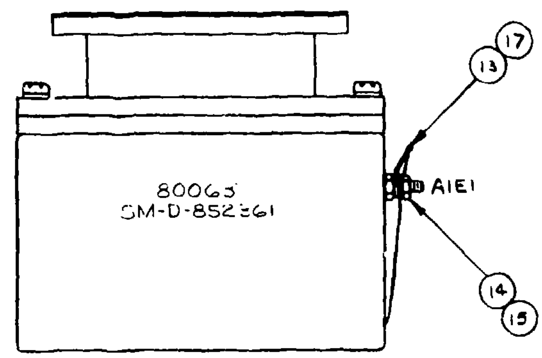

SEE N

22.00

NOTES:
1. WORKMANSHIP SHALL BE IN ACCORDANCE WITH MIL-STD-454, REQT 9.
2. FOR SCHEMATIC DIAGRAM SEE SM-D-852405.
3. TOLERANCE ON CABLE LENGTHS SHOWN ±.25.
4. SOLDER IN ACCORDANCE WITH MIL-STD-454, REQT 5 USING ITEM 17.
5. MARK WITH .12 HIGH GOTHIC CHARACTERS USING ITEM 39 LOCATED APPROX AS SHOWN
6. HOT STAMP MARKINGS ON ITEMS 34 AND 35 USING CONTRASTING COLOR FOIL PER ITEM 16. HEIGHT .09 MIN.
7. AFTER FINAL ASSY OF P1, FILL POTTING SHELL WITH ITEM 18.
8. VENDOR ITEM, SEE SPECIFICATION OR SOURCE CONTROL DRAWING.
9. TEST IN ACCORDANCE WITH SM-A-852451.
10. AFTER ELECTRICAL TEST, FILL CAVITY WITH ITEM 18.

2	B
1	B
SHT	REV
REV STATUS	

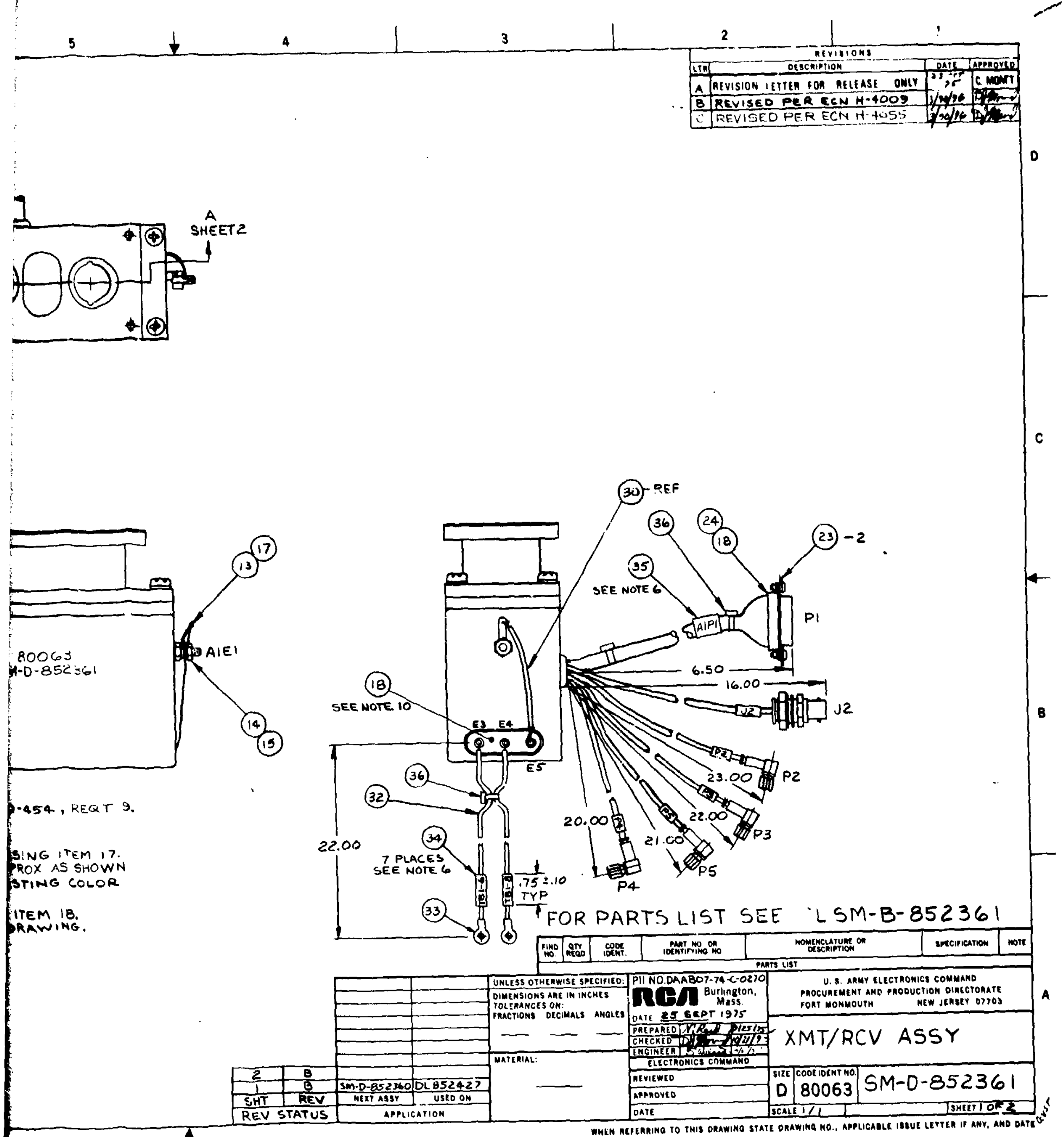

Figure 2-22. STE Transmitter/ Receiver Assembly

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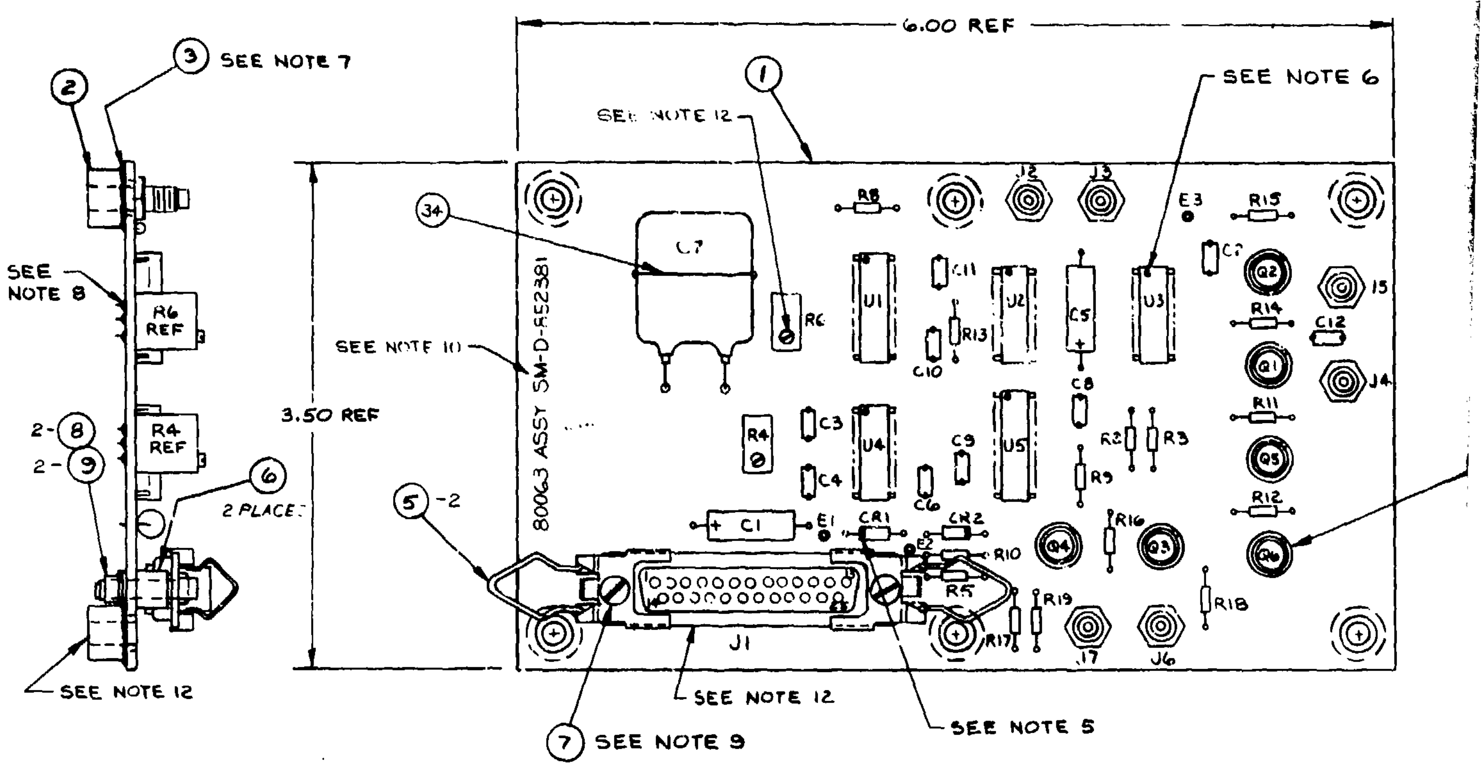
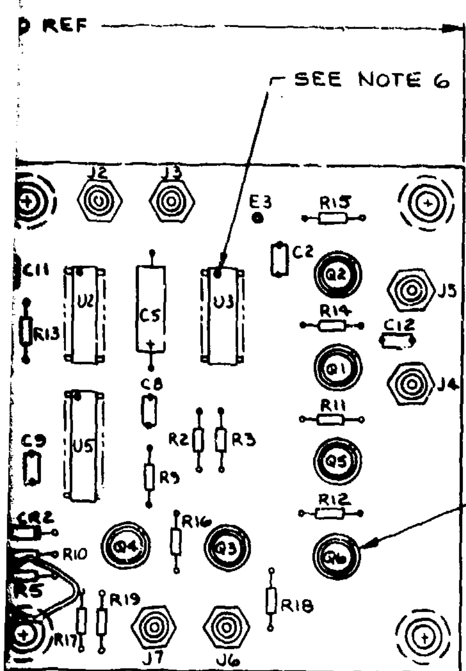


NOTES:

1. WORKMANSHIP SHALL BE IN ACCORDANCE WITH MIL-STD-454 REQT 9.
2. FOR SCHEMATIC DIAGRAM SEE SM-D-852382
3. SOLDER PER MIL-STD-454 REQT 5 USING SOLDER PER ITEM 32.
4. PARTIAL REFERENCE DESIGNATIONS ARE SHOWN, FOR COMPLETE DESIGNATION PREFIX WITH UNIT NUMBER OR SUBASSY DESIGNATION(S).
5. BAR DENOTES CATHODE END OF DIODE.
6. DOT INDICATES PIN NO. 1 ON INTEGRATED CIRCUIT.
7. BOND ITEM 2 TO ITEM 1 USING ITEM 3.
8. COMPONENT LEADS AND SOLDER BUILD-UP SHALL NOT EXCEED .09 ON NON-COMPONENT SIDE OF BOARD.
9. ASSEMBLE J1 TO ITEM 1 AND TIGHTEN MTG SCREWS BEFORE SOLDERING IN PLACE.
10. MARK .12 HIGH STANDARD CHARACTERS PER MIL-M-13231 LOCATE APPROXIMATELY AS SHOWN.
11. TEST IN ACCORDANCE WITH SM-A-852447.
12. MASK E1, E2, E3, J2 THRU J7, ADJ SCREWS OF R6 & R4, CONN. J1 AND MTG SPACERS PRIOR TO CONFORMAL COAT
13. CONFORMAL COAT ASSY USING TYPE UR COATING USING ITEM 36.
14. VENDOR ITEM, SEE SPECIFICATION OR SOURCE CONTROL DRAWING.

LTR	DESCRIPTION	DATE	APPROVED
A	REVISION LETTER FOR RELEASE ONLY		C. MGMT
B	REVISED PER ECN H-4012		
C	REVISED PER ECN NO. H-4040		



SEE NOTE 5

-454 REQT 9.

PER ITEM 32.
COMPLETE DESIGNATION
ION(S).

T EXCEED .09 ON

FORE SOLDERING IN PLACE.
ATE APPROXIMATELY AS SHOWN.

MTG SPACERS PRIOR TO CONFORMAL COAT.
ING ITEM 36.
WING.

REF DES	FIND NO.
DELETED	10
R3, R14 THRU R17	11
R2	12
R4	13
R5, R8	14
R6	15
R11, R12	16
R13, R10	17
R9	18
R18, R19	19
C1, C5	20
C3, C6	21
C2, C11, C12, C4	22
C8, C9, C10	23
CR1, CR2	24
U1, U5	25
U4	26
U2 U3	27
Q5, Q6	28
Q1, Q2, Q3, Q4	29
J1	30
J2 THRU J7	31
E1, E2, E3	33
C7	37

FOR PARTS LIST SEE PL SM-B-852381

FIND NO	QTY REQD	CODE IDENT	PART NO. OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	SPECIFICATION	NOTE

PARTS LIST

SM-D-852380	DL 852428
NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES. TOLERANCES ON FRACTIONS DECIMALS ANGLES — — —

MATERIAL: —

PII NO DAAB07-74-C-0270

RCA Burlington, Mass

DATE 3 OCT 1975

PREPARED / CHECKED / ENGINEER

ELECTRONICS COMMAND

REVIEWED

APPROVED

DATE

U. S. ARMY ELECTRONICS COMMAND
PROCUREMENT AND PRODUCTION DIRECTORATE
FORT MONMOUTH NEW JERSEY 07703

BOARD ASSEMBLY, ELECTRONICS

SIZE D CODE IDENT NO 80063 SM-D-852381

SCALE 2/1 SHEET 1 OF 1

WHEN REFERRING TO THIS DRAWING STATE DRAWING NO., APPLICABLE ISSUE LETTER IF ANY, AND DATE

Figure 2-23. STE Electronics Board Assembly

8	7	6	5	4

NOTE
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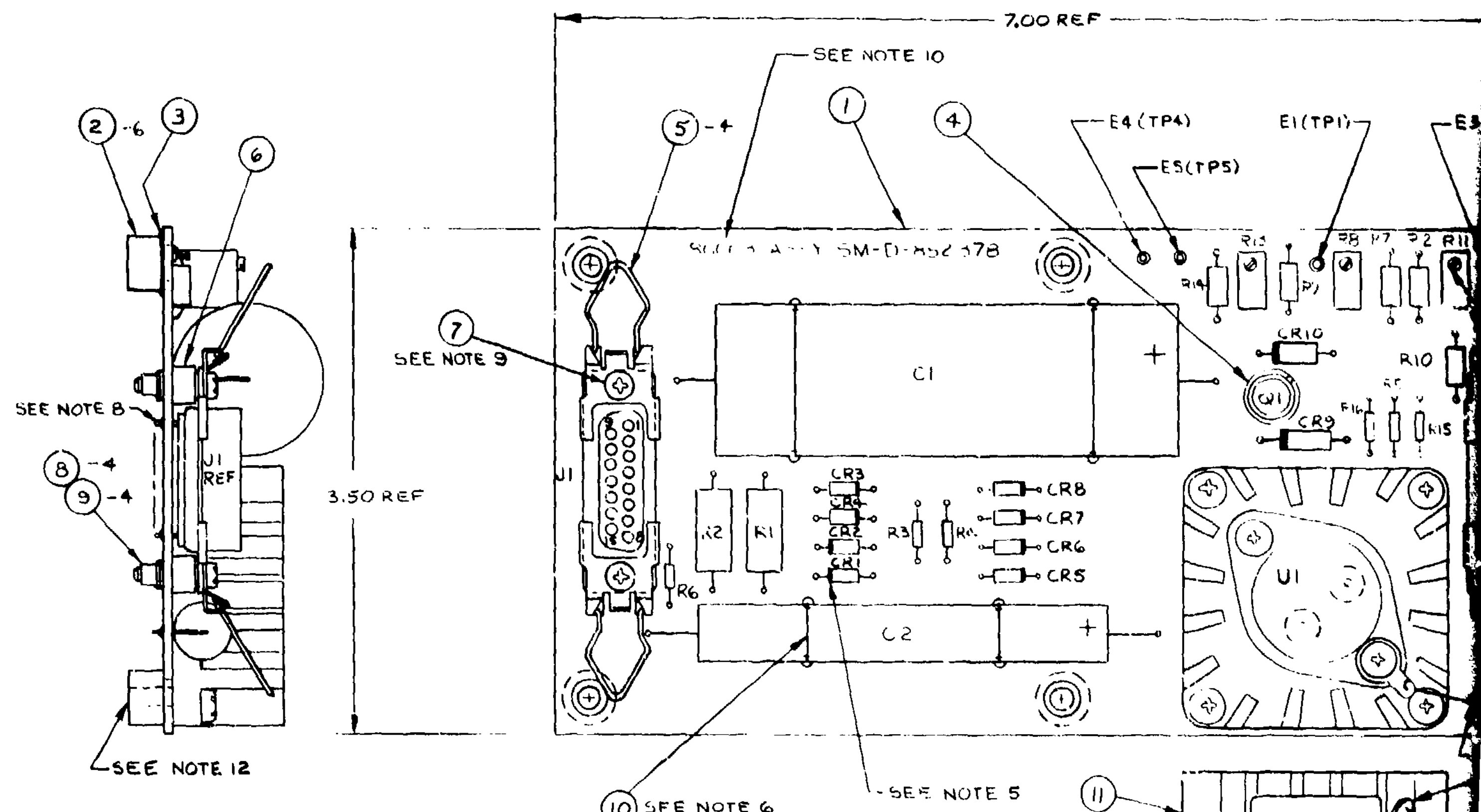
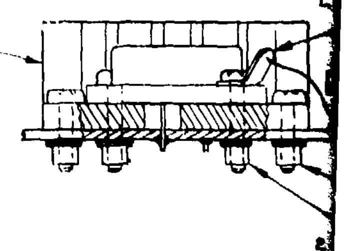
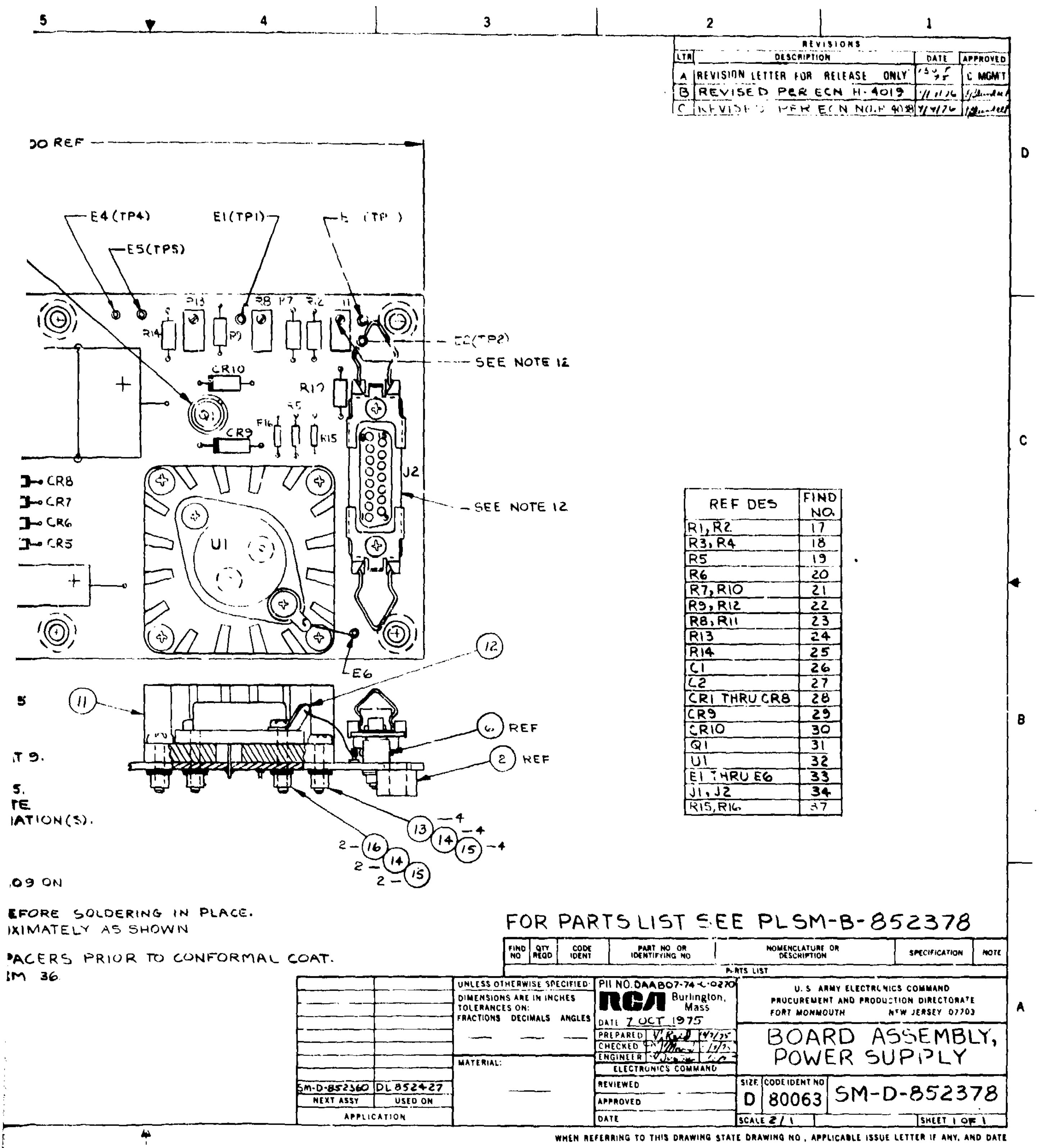




NOTES:
1. WORKMANSHIP SHALL BE IN ACCORDANCE WITH MIL-STD-454 REQT 9.
2. FOR SCHEMATIC DIAGRAM SEE SM-D-852379.
3. SOLDER PER MIL-STD-454 REQTS USING SOLDER PER ITEM 35.
4. PARTIAL REFERENCE DESIGNATIONS ARE SHOWN, FOR COMPLETE DESIGNATION PREFIX WITH UNIT NUMBER OR SUBASSY DESIGNATION(S).
5. BAR DENOTES CATHODE END OF DIODE
6. MECHANICALLY SECURE C1 AND C2 TO ITEM 1 USING ITEM 10.
7. BOND ITEM 2 TO ITEM 1 USING ITEM 3.
8. COMPONENT LEADS AND SOLDER BUILD-UP SHALL NOT EXCEED .09 ON NON-COMPONENT SIDE OF BOARD.
9. ASSEMBLE J1 AND J2 TO ITEM 1 AND TIGHTEN MTG SCREWS BEFORE SOLDERING IN PLACE.
10. MARK .12 HIGH STANDARD CHARACTERS PER MIL-M-13231 LOCATE APPROXIMATELY AS SHOWN
11. TEST IN ACCORDANCE WITH SM-A-852448.
12. MASK ADJUSTING SCREWS OF R13,R8,R11,J1,J2, E1 THRU E5 & MTG SPACERS PRIOR TO CONFORMAL COAT.
13. CONFORMAL COAT ASSY USING TYPE UR COATING PER ITEM 36
14. VENDOR ITEM, SEE SPECIFICATION OR SOURCE CONTROL DRAWING.

SM-D-
NEXT



REF DES	FIND NO.
R1, R2	17
R3, R4	18
R5	19
R6	20
R7, R10	21
R9, R12	22
R8, R11	23
R13	24
R14	25
C1	26
C2	27
CR1 THRU CR8	28
CR9	29
CR10	30
Q1	31
U1	32
E1 THRU E6	33
J1, J2	34
R15, R16	37

Figure 2-24. STE Power Supply Printed Wiring Board

2.3.2 Electronic Design

2.3.2.1 Functional Requirements

The STE has five modes of operation, each having the functional capabilities outlined below.

(1) 1 TGT Mode - The STE transmits a single optical pulse to the LRF for each received optical pulse. The transmitted pulse is delayed from the received pulse by 32 ± 1.34 microseconds which corresponds to an LRF range reading of 4,800 ± 200 meters.

(2) 2 TGT Mode - In the 2 TGT Mode, a pair of optical pulses are transmitted to the LRF for each received optical pulse. The pair of pulses are delayed from the received pulse by 32 ± 1.34 microseconds (4,800 ± 200 meters) and are spaced 0.7 ± 0.2 microseconds (≈100 meters).

(3) RCVR 1 PULSE Mode - In the RCVR 1 PULSE mode, an optical pulse is transmitted to the LRF at a 50 pps rate. This pulse contains twice the normal transmitted power.

(4) RCVR 2 PULSE Mode - In the RCVR 2 PULSE position, a pair of pulses are transmitted to the LRF at a 50 ± 10 pps rate. The pulse spacing between the pair of pulses is 0.7 ± 0.2 microseconds.

(5) LASER PULSE MONITOR Mode - The LASER PULSE MONITOR mode is functionally identical to the 1 TGT mode. It is included as a separate mode because the STE calibrations are not required when monitoring the pulse.

In addition to the mode selection, there are several other functions provided for in the STE.

(1) LASER POWER INDICATORS - Two laser power indicators are provided. The low power indicator is a red light that is turned on whenever the received optical energy exceeds 6 millijoules and the normal power indicator light is off. The normal power indicator is a green light which is turned on whenever the received optical energy is above 8.0 ± 0.5 millijoules. Both lights remain on until reset by depressing the RESET button.

(2) SYNC PULSES - To facilitate troubleshooting the LRF, two syncronizing pulses are provided; first, TGT SYNC pulse is generated prior to each

transmitted optical pulse or pulse pair in all operating modes, second, a RCVR SYNC pulse is generated for each received optical pulse. Both syncronizing pulses are available on the front panel and will drive a terminated 50 ohm coaxial cable.

(3) LASER PULSE MONITOR - An additional jack on the front panel is the LASER PWR MONITOR which allows monitoring of the receiver PIN output. This jack is not used during LR testing.

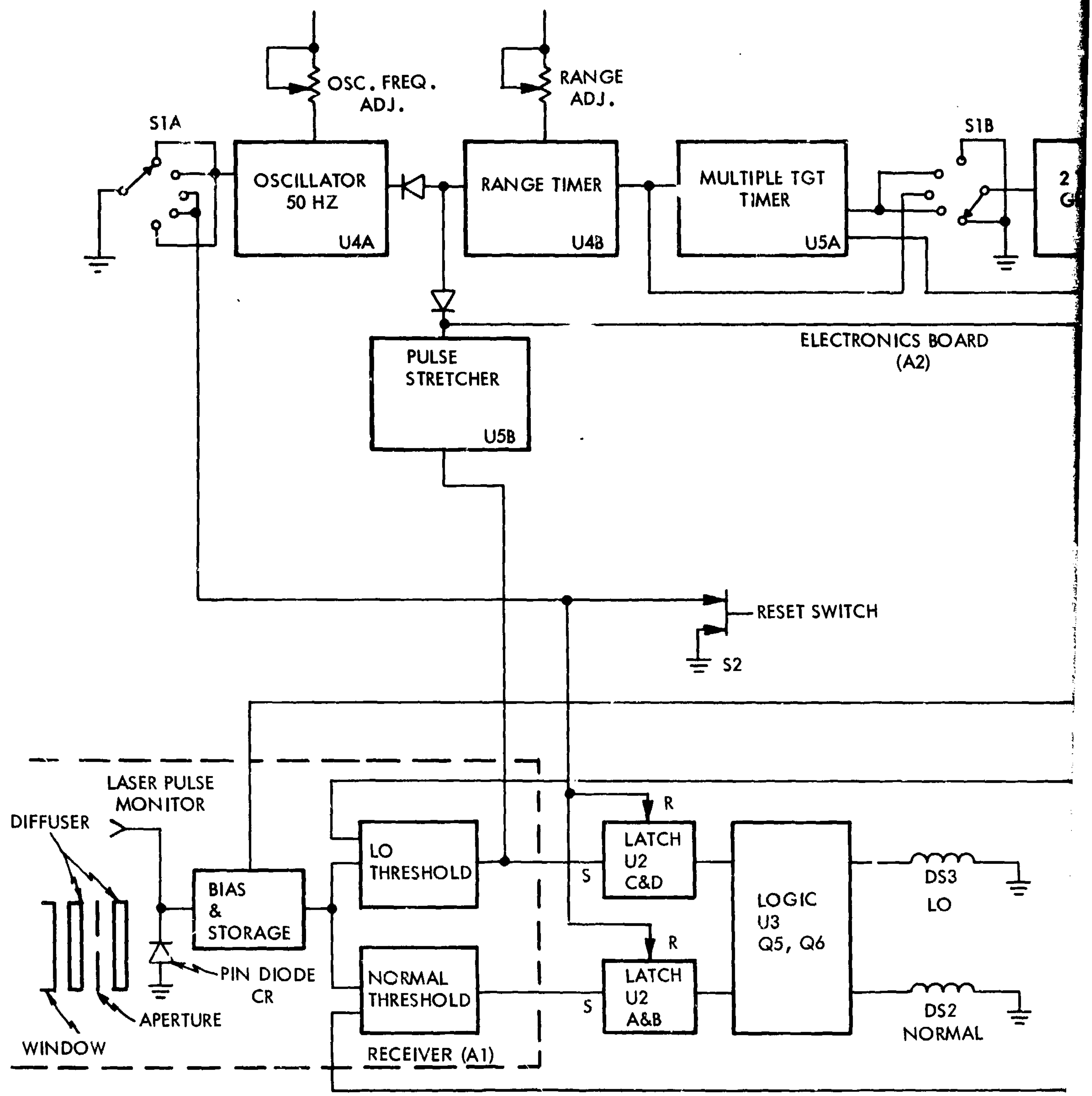
2.3.2.2 Circuit Design

Figure 2-25 is a simplified overall block diagram of the Test Set. Figures 2-26, 2-27, and 2-28 are the electrical schematics of the three boards used in the STE.

2.3.2.2.1 Operation

Optical energy from the LRF is diffused and attenuated in the receiving optics. The diffusion provides a uniform spatial distribution to minimize the LRF alignment sensitivity. The aperture reduces the LRF output to a safe level for the PIN diode detector (CR-5).

The PIN diode detects the received optical pulse and converts the optical power to a charge which is stored in a capacitor. The output voltage of the capacitor, which is proportional to optical energy, is compared to two reference voltages. One comparison is made in the LO power comparator (U1-A) and the other in the NORMAL power comparator (U1-B).


OSC. FREQ. ADJ.
RANGE ADJ.
S1A
S1B
OSCILLATOR 50 HZ
U4A
RANGE TIMER
U4B
MULTIPLE TGT TIMER
U5A
PULSE STRETCHER
U5B
ELECTRONICS BOARD (A2)
RESET SWITCH
S2
LASER PULSE MONITOR
DIFFUSER
BIAS & STORAGE
LO THRESHOLD
NORMAL THRESHOLD
PIN DIODE CR
APERTURE
WINDOW
RECEIVER (A1)
LATCH U2 C&D
LATCH U2 A&B
R
S
LOGIC U3 Q5, Q6
DS3 LO
DS2 NORMAL

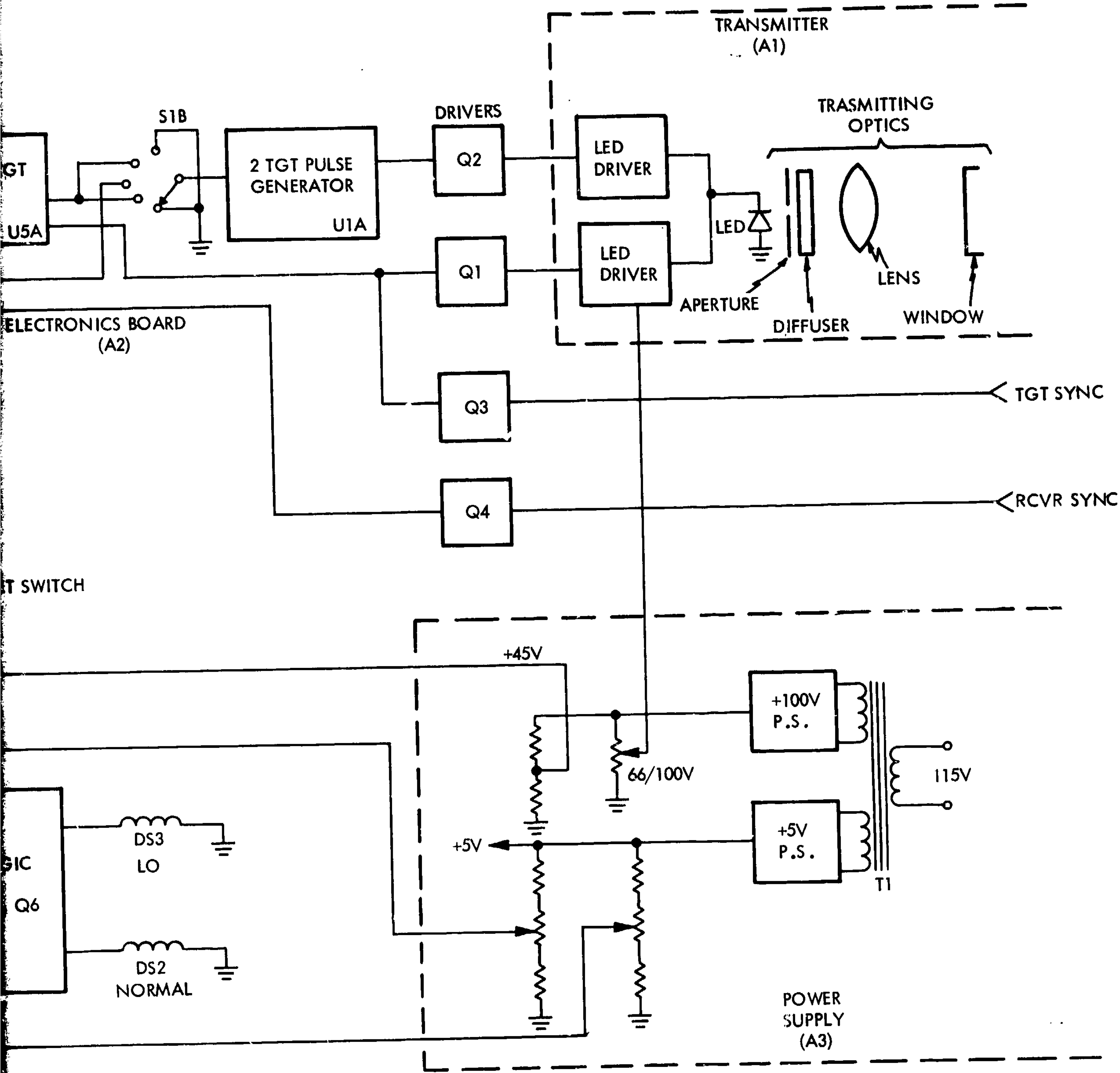


Figure 2-25. STE Functional Block Diagram

8 | 7 | 6 | 5 | 4

NOTE
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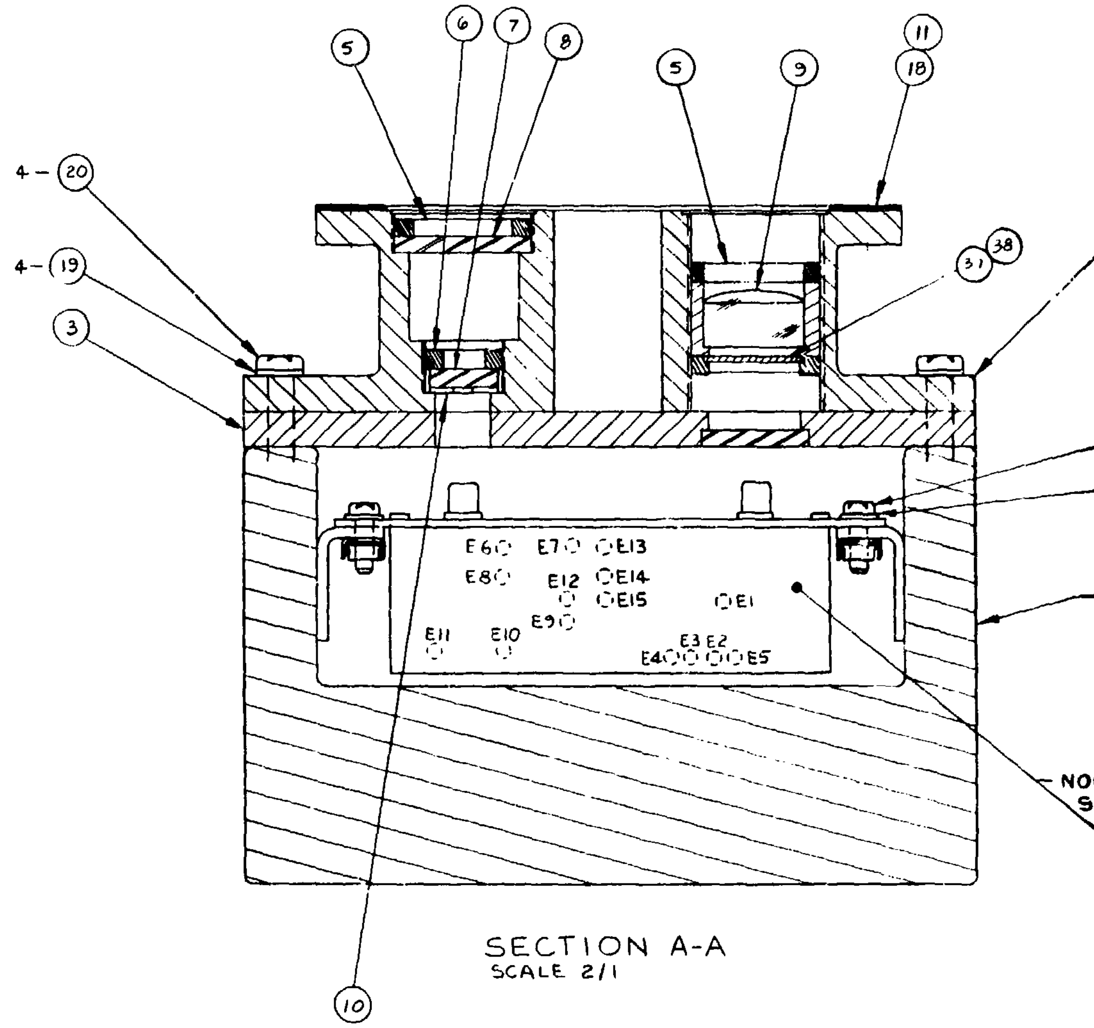
D

C

WIRING TABLE		
FROM	TO	FIND NO.
A1A1-E13	P1-13	30
A1A1-E10	P1-12	29
A1A1-E6	P1-2	31
A1A1-E1	P1-3	31
A1A1-E8	P1-11	29
A1A1-E9	P1-14	29
A1A1-E2 A1A1-E5	P4 SHLD	28
A1A1-E3 A1A1-E4	P5 SHLD	28
A1A1-E12 A1A1-E15	P2 SHLD	28
A1A1-E11 A1A1-E14	P3 SHLD	28
A1A1-E7 A1A1-E13	J2 SHLD	28
A1-E5	A1-E1	16
A1-E1	A1-E2	16
A1-E3	TB1-6	37
A1-E4	TB1-8	37



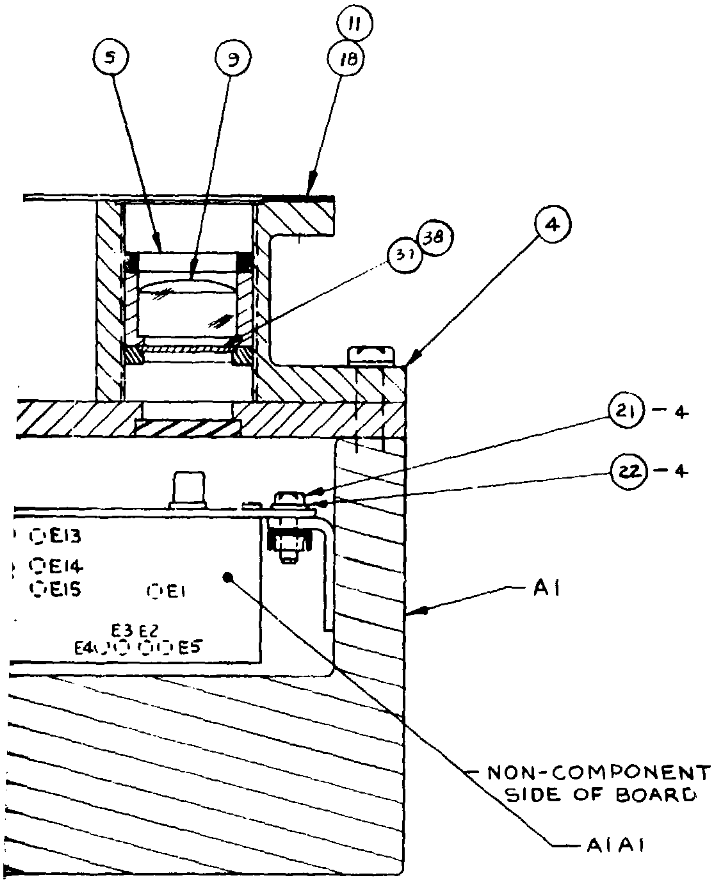
SECTION A-A
SCALE 2/1

B

A

SM-D-8
NEXT

LTR	DESCRIPTION	DATE	APPROVED
B	REVISED PER ECN H-4009	3/30/76	
C	REVISED PER ECN H-4055	5/4/76	



TION A-A
2/1

REF DES	FIND NO.
A1A1	1
A1	2
P1	25
P2 THRU P5	27
A1E1	13
J2	26

FIND NO	QTY REQD	CODE IDENT.	PART NO. OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	SPECIFICATION	NOTE

PARTS LIST

SM-D-852360	DL 852427
NEXT ASSY	USED ON
APPLICATION	

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MATERIAL: —

PII NO. DAAB07-74-C-0270

RCA Burlington, Mass.

DATE 25 SEPT 1975

PREPARED
CHECKED
ENGINEER

ELECTRONICS COMMAND
REVIEWED
APPROVED
DATE

U. S. ARMY ELECTRONICS COMMAND
PROCUREMENT AND PRODUCTION DIRECTORATE
FORT MONMOUTH NEW JERSEY 07703

XMT/RCV ASSY

SIZE	CODE IDENT NO.	
D	80063	SM-D-852361

SCALE 2/1 SHEET 2

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Figure 2-26. STE Transmit/Receive Electrical Schematic

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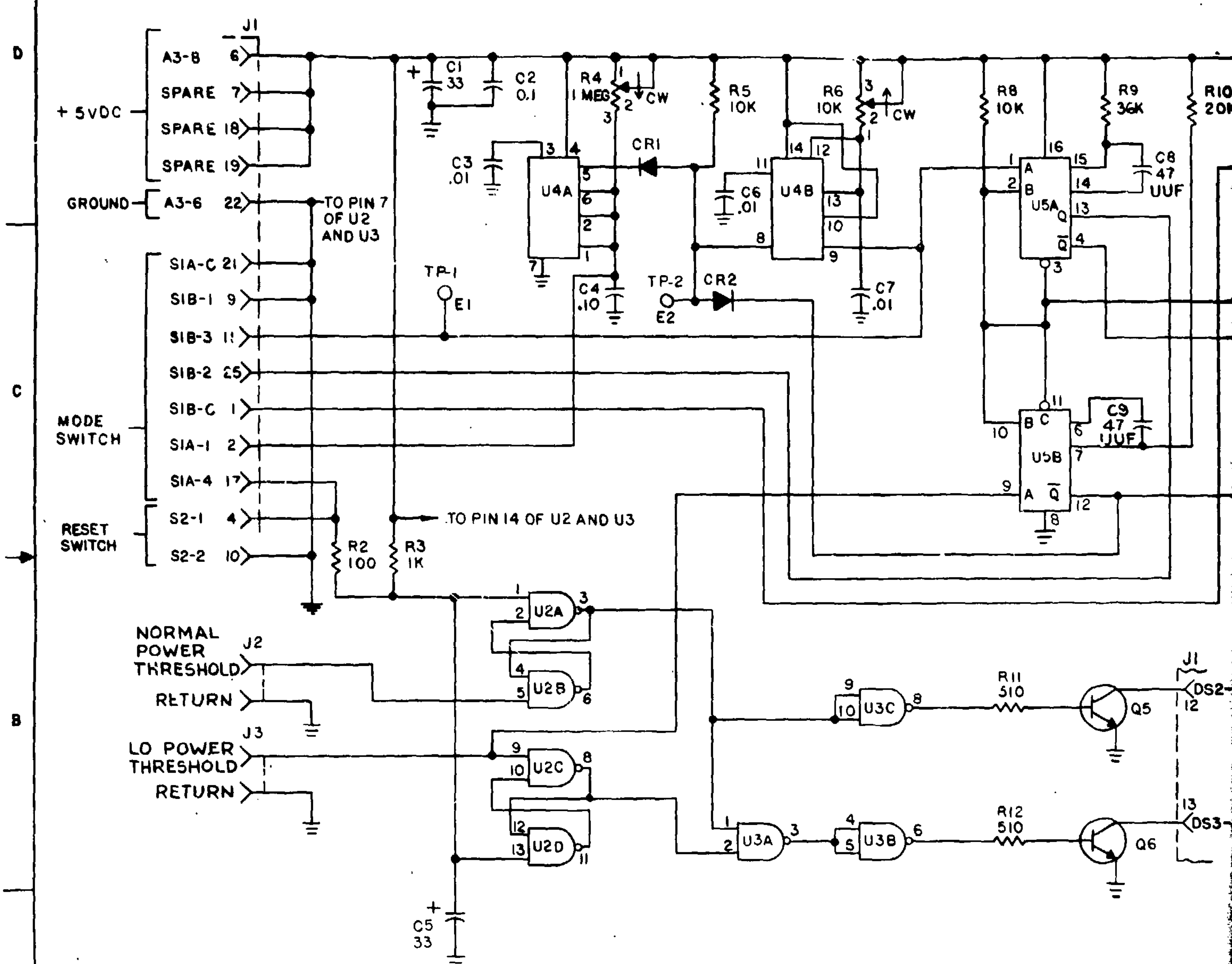
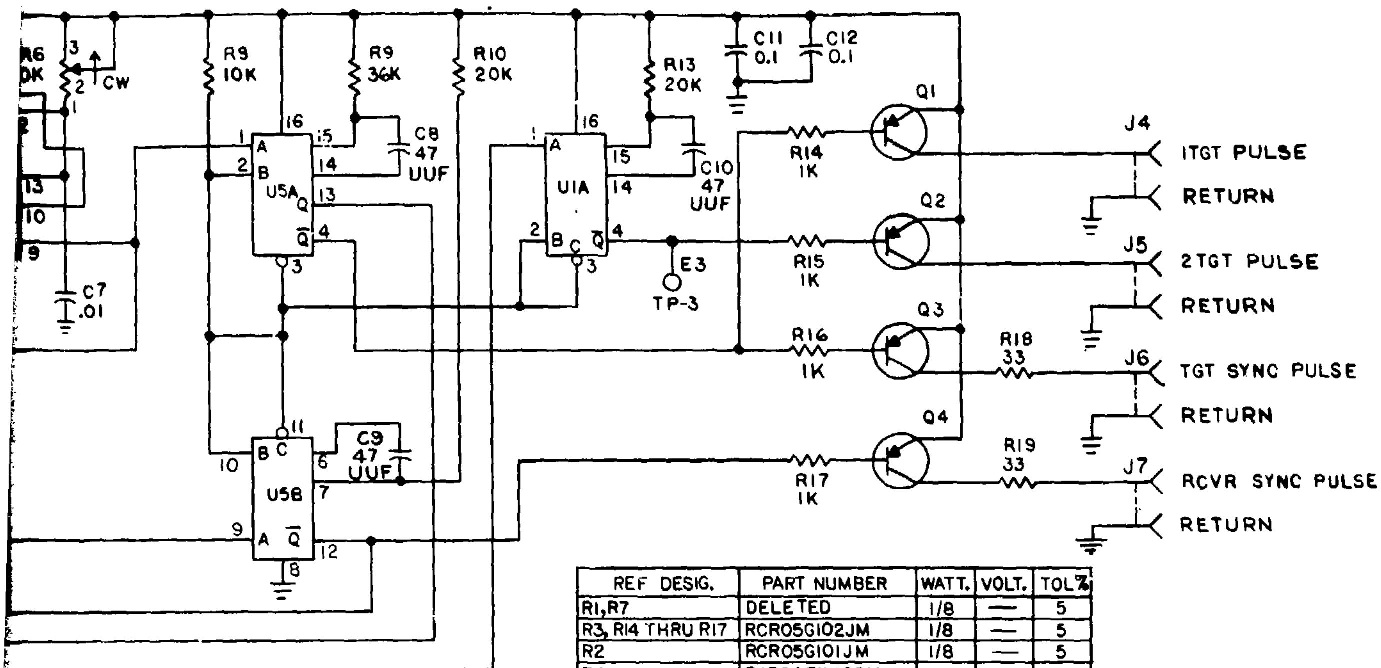
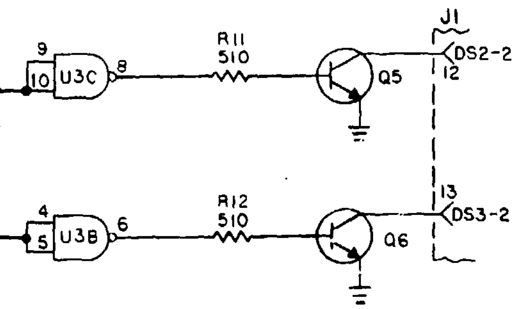


NOTES:
1. UNLESS OTHERWISE SPECIFIED,
   RESISTANCE VALUES ARE IN OHMS,
   CAPACITANCE VALUES ARE IN MICROFARADS.
2. PARTIAL REFERENCE DESIGNATIONS ARE SHOWN FOR COMPLETE DESIGNATION PREFIX WITH SUBASSEMBLY DESIGNATION (J).

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED
A	REVISION LETTER FOR RELEASE	[illegible]	[illegible]
B	REVISED PER ECN H-4006	4/9/76	[illegible]
C	REVISED PER ECN NO. H-4035	4/9/76	[illegible]





REF DESIG.	PART NUMBER	WATT.	VOLT.	TOL%
R1,R7	DELETED	1/8	—	5
R3, R14 THRU R17	RCR05G102JM	1/8	—	5
R2	RCR05G101JM	1/8	—	5
R4	RJR24FW105M	—	—	—
R5,R8	RCR05G103JM	1/8	—	5
R6	M39015/3-010WM	—	—	—
R11,R12	RCR05G511JM	1/8	—	5
R13,R10	RCR05G203JM	1/8	—	5
R9	RCR05G263JM	1/8	—	5
R18,R19	RCR05G330JM	1/8	—	5
C1,C5	M39003/01-2258	—	10	20
C3,C6	M39014/01-1455	—	100	10
C2,C11,C12,C4	M39014/01-1473	—	50	10
C8,C9,C10	M39014/01-1213	—	200	10
CR1,CR2	JAN1N4148	—	—	—
U1,U5	M38510/01203BEB	—	—	—
U4	SM-B-852359	—	—	—
U2,U3	M38510/00104BCB	—	—	—
Q5,Q6	JAN2N2222	—	—	—
Q1 THRU Q4	JAN2N2907A	—	—	—
J1	M24308/24-3	—	—	—
J2 THRU J7	SM-B-852376	—	—	—
E1,E2,E3	M55155/29-5	—	—	—
C7	CMR07103J0DM		500	5

FIND NO.	QTY REQD	CODE IDENT	PART NO. OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	SPECIFICATION	NOTE

PARTS LIST

NEXT ASSY	USED ON
SM-D-852381	DL-852428

APPLICATION

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES ON:
FRACTIONS DECIMALS ANGLES
—
MATERIAL:

PII NO. DAAB07-74-C-0270
RCA Burlington, Mass
DATE Sept 11-75
PREPARED
CHECKED
ENGINEER
ELECTRONICS COMMAND
REVIEWED
APPROVED
DATE

U. S. ARMY ELECTRONICS COMMAND
PROCUREMENT AND PRODUCTION DIRECTORATE
FORT MONMOUTH NEW JERSEY 07703

ELECTRICAL SCHEMATIC,
ELECTRONICS BOARD

SIZE D | CODE IDENT NO. 80063 | SM-D-852382

SCALE — SHEET 1 OF 1

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Figure 2-27. STE Electronics Board, Electrical Schematic

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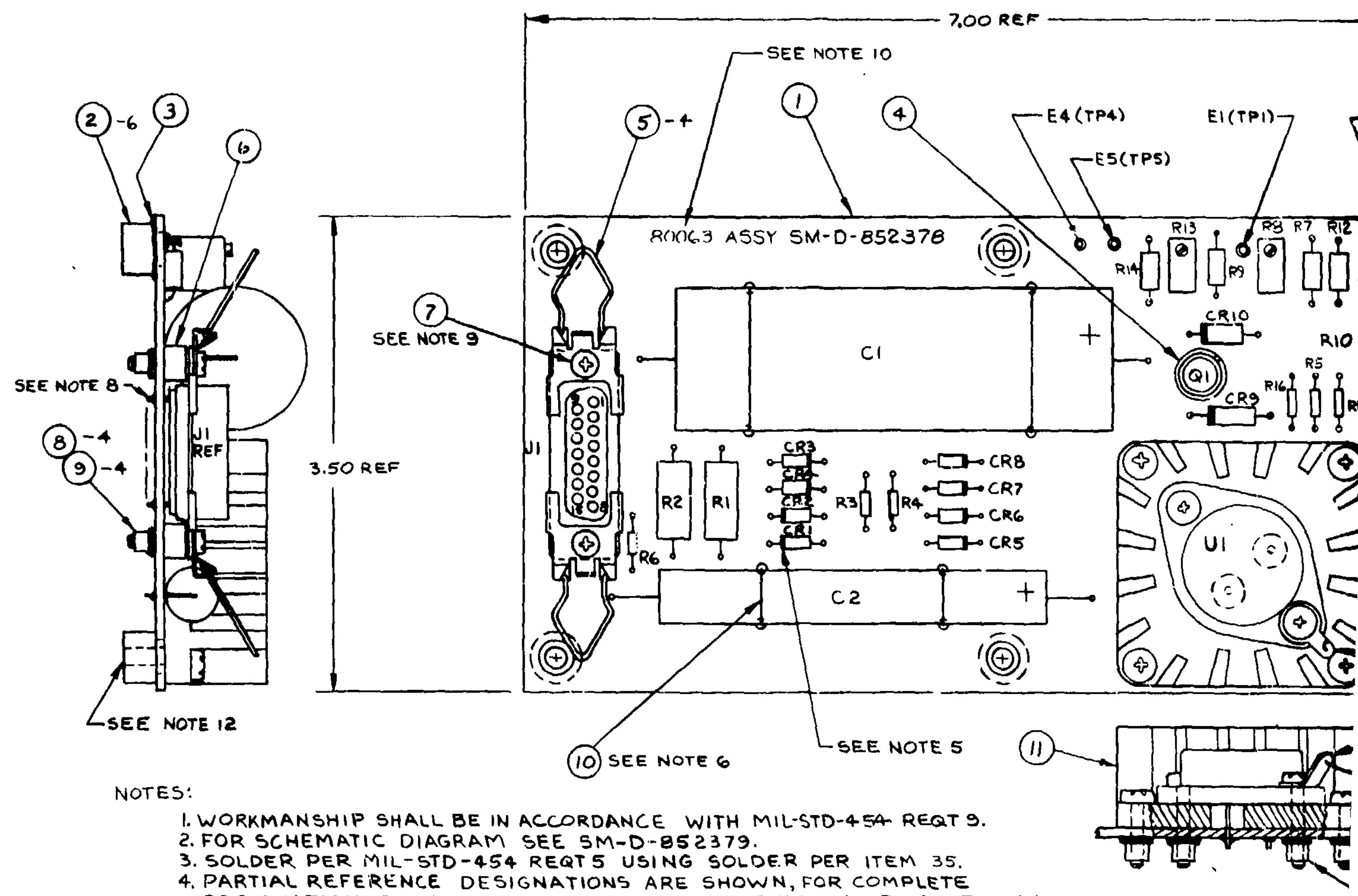
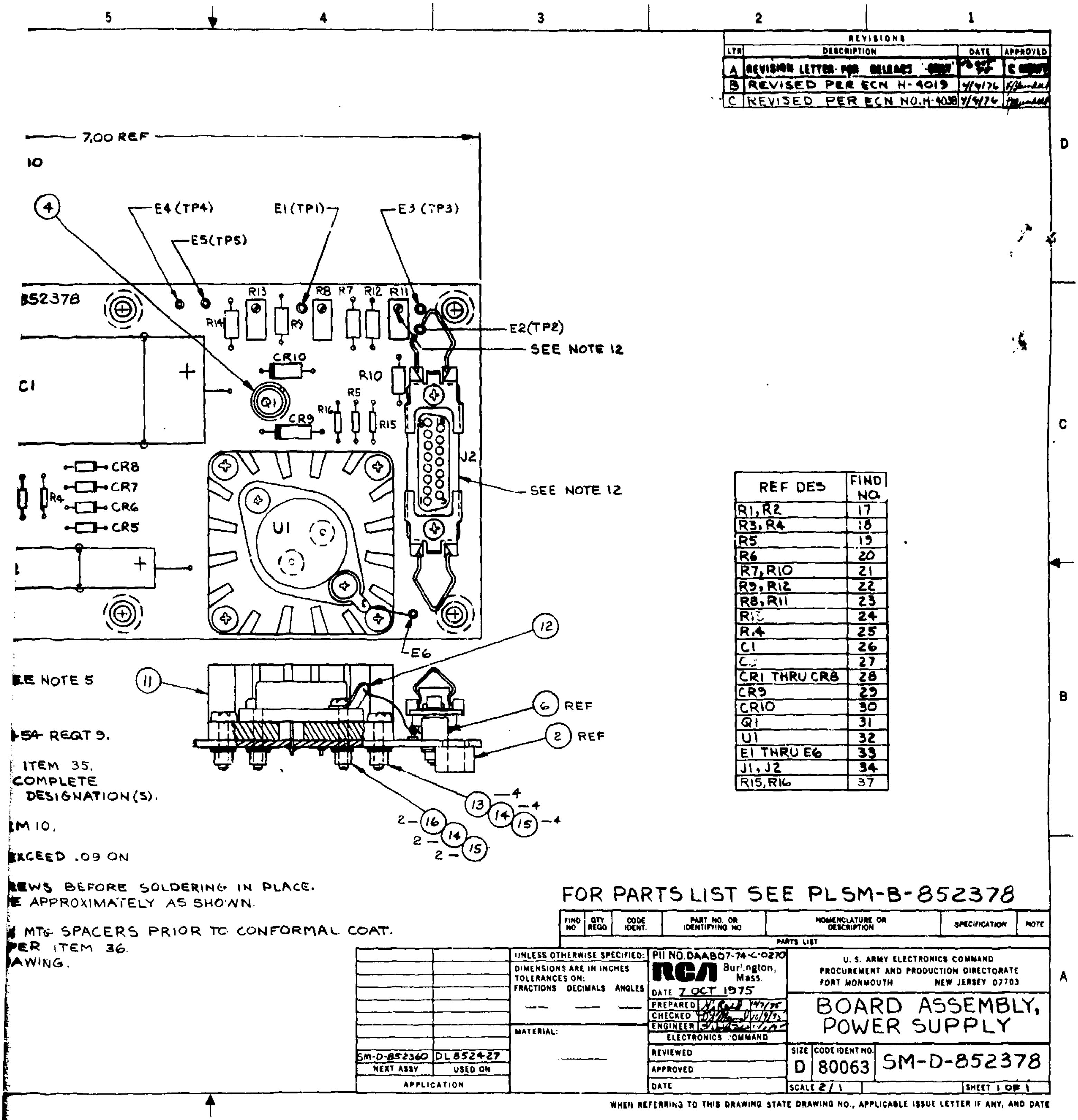


NOTES:

1. WORKMANSHIP SHALL BE IN ACCORDANCE WITH MIL-STD-454 REQT 9.
2. FOR SCHEMATIC DIAGRAM SEE SM-D-852379.
3. SOLDER PER MIL-STD-454 REQT 5 USING SOLDER PER ITEM 35.
4. PARTIAL REFERENCE DESIGNATIONS ARE SHOWN, FOR COMPLETE DESIGNATION PREFIX WITH UNIT NUMBER OR SUBASSY DESIGNATION(S).
5. BAR DENOTES CATHODE END OF DIODE
6. MECHANICALLY SECURE C1 AND C2 TO ITEM 1 USING ITEM 10.
7. BOND ITEM 2 TO ITEM 1 USING ITEM 3.
8. COMPONENT LEADS AND SOLDER BUILD-UP SHALL NOT EXCEED .09 ON NON-COMPONENT SIDE OF BOARD.
9. ASSEMBLE J1 AND J2 TO ITEM 1 AND TIGHTEN MTG SCREWS BEFORE SOLDERING IN PLACE.
10. MARK .12 HIGH STANDARD CHARACTERS PER MIL-M-13231 LOCATE APPROXIMATELY AS SHOWN
11. TEST IN ACCORDANCE WITH SM-A-852448.
12. MASK ADJUSTING SCREWS OF R13, R8, R11, J1, J2, E1 THRU E5 & MTG SPACERS PRIOR TO CONFORMAL COA
13. CONFORMAL COAT ASSY USING TYPE UR COATING PER ITEM 36.
14. VENDOR ITEM, SEE SPECIFICATION OR SOURCE CONTROL DRAWING.



REF DES	FIND NO.
R1, R2	17
R3, R4	18
R5	19
R6	20
R7, R10	21
R9, R12	22
R8, R11	23
R13	24
R14	25
C1	26
C2	27
CR1 THRU CR8	28
CR9	29
CR10	30
Q1	31
U1	32
E1 THRU E6	33
J1, J2	34
R15, R16	37

Figure 2-28. STE Power Supply, Electrical Schematic

If the capacitor voltage exceeds the LO power threshold, the comparator output drives the power monitor logic (U2, U3) and turns on the LO PWR monitor light (DS-3). In addition, the low power threshold output drives a pulse stretcher (U5B) which, in turn, starts a range timer (U4B) and generates a sync pulse at the receiver sync jack (J7). If the capacitor voltage exceeds the high power threshold voltage, the high power threshold output drives the power monitor logic (U2, U3) which turns off the LO PWR indicator (DS-3) and turns on the NORMAL PWR indicator (DS-2).

The range timer (U4B), after timing out, triggers the multiple target timer (U5A) and, if the mode switch (S1) is in the RCVR/PULSE position, the 2 TGT pulse generator (U1A). The output of the multiple target timer (U5A) is a pulse 0.7 $\pm$ 0.2 microseconds wide which drives the 1 TGT and TGT SYNC line driver (Q_1 & Q_3).

The TGT sync line connects to a BNC receptacle on the front panel where it is available for troubleshooting the LRF. The 1 TGT line goes to the LED driver circuit in the XMT/RCV assembly. This circuit discharges a capacitor timed by the leading edge of the pulse, through a light emitting diode (CR3) to generate an output optical pulse at 1064 nanometers. The output of the LED is diffused and partially collinated in the transmitting optics. The diffusion and collination illuminate the receiving diode in the LRF with a uniform light energy without requiring a critical optical alignment between the LRF and the test set.

In the 2 TGT and RCVR 2 PULSE modes a pair of pulses are required with a spacing of 0.7 $\pm$ 0.2 microseconds. The second pulse is generated by using the trailing edge of the multiple target timer output (U5A) to trigger the 2TGT pulse generator (U1A). The pulse width of the multiple target timer is the required 0.7 $\pm$ 0.2 microseconds.

The output of the 2 TGT pulse generator (U1A) drives Q_2 which, in turn, drives a second LED driver circuit in the XMT/RCV assembly. This LED driver discharges a second capacitor through the LED to produce an optional pulse with the same characteristics as the first but delayed by a time equivalent to a target separation range of approximately 100 meters.

In the RCVR 1 PULSE and RCVR 2 PULSE modes an oscillator (U4A) is turned on by removal of a short across an integrator. This oscillator triggers the range timer every 20 milliseconds. The remaining operations are identical to those previously discussed except that no RCVR SYNC pulse is generated and no indicator light is turned on.

2.3.2.2.2 Power Supply

The power supply consists of two separate supplies with output voltages of +5.0 ± 0.3 volts and +100 ± 4 volts. Both supplies use full wave bridge rectifiers and series regulators. The power supply board contains three adjustments. The LO and NORMAL power threshold voltages provide a fine adjustment for receiver sensitivity. The transmitter high voltage adjust provides a find adjust on the transmitted power out.

2.3.2.2.3 Additional Adjustments Required

The test oscillator frequency is adjusted to 50 ± 10 Hz by a potentiometer on the electronics board. The range timing, adjusted to 32 ± 1.34 microseconds (4,800 ± 200 meters) by a potentiometer on the electronics board, includes both the transmitter and receiver delays. The receiver sensitivity coarse adjustment is accomplished by means of an aperture in the optics assembly. The transmitter power output coarse adjustment is by means of an aperture in the transmitting optics.

2.3.3 Calibration

2.3.3.1 LED Source

The LED selected for the STE transmitter is an RCA Indium Gallium Arsenide type C30116. Because of the variation in the center wavelength of its output spectrum, the diodes in the STE are selected to be 1,064 ± 5 nanometers. The optical power output of the STE is adjusted during calibration by varying the transmitter high voltage (66/100 V) and the aperture size of the output optics. The power is measured by a calibrated standardized rangefinder as outlined below in paragraph 2.3.3.3.

2.3.3.2 Detector and Threshold Circuits

The optical detector selected for the STE is an RCA PIN diode with a sensitivity of 0.2 amperes/watt. A fixed bias voltage of 45 volts is applied to the diode. To adjust the STE receiver sensitivity, an adjustable aperture size and detector threshold level is used. The actual calibration will be done using the standardized rangefinder (paragraph 2.3.3.3). For a full discussion of the calibration procedure refer to SM-D-852450.

2.3.3.3 Standardized Rangefinder

In order to calibrate the STE transmitter and receiver a calibrated source and detector are required. This source and detector should have characteristics of wavelength, optical bandwidth, and optical beamwidth as close to those in the LRF as possible. For this reason, as well as to minimize development costs, an LRF is used as both the source and detector of the calibration fixture, referred to as a "standardized rangefinder". The modifications to the off-the-shelf LRF are as follows.

The LRF is selected for high output power (minimum 16 millijoules) to allow for losses in a beam sampler, and aperture adjustment. The output of the transmitter is fed through an adjustable aperture to set its output power. The output power is sampled on a pulse-to-pulse basis by a laser beam sampler and read on a calibrated radiometer.

The above modifications provide a calibrated pulse with the proper pulse width and wavelength against which the STE thresholds can be adjusted. The calibrated LRF transmitter requires a special mount to accommodate the sampler and adjustable aperture. This does not create an alignment problem since the STE receiving port contains a diffuser and small aperture rather than a lens system.

To modify the LRF for use as a calibrated receiver, it is necessary to open the AGC loop between the video amplifier and the power supply and substitute a stable adjustable voltage to the power supply input. In addition, the output of the video amplifier is brought out to a test jack. To calibrate the modified LRF receiver, a transfer method is used to transfer the calibration of a PIN diode to the LRF receiver.

The essentials of the calibration are as follows. An LED with a spectrial response centered at 1.064 microns is pulsed at a low fixed PRF. This is followed by a spectral filter identical to or having a smaller bandwidth than that used in the LRF. This insures that all of the calibrated energy falls within the bandwidth of LRF under test.

The output of the spectral filter is fed through a lens to provide a beam sufficiently well collimated to avoid calibration variations due to small changes in distance between the source and detectors.

The lens is followed by an aperture with an area of $31.7mm^2$. This reduces the beam diameter to a point where all the beam energy is collected on a PIN diode with an area of $100mm^2$ aligned coaxially with the aperture. The output of the PIN diode is amplified by a known fixed gain amplifier and read on an oscilloscope.

The power can then be computed by knowing the aperture area, the diode calibration, the amplifier gain, and load resistance.

$$\text{Peak Power } (^{W}/\text{mm}^2) = \frac{\text{Peak Video Amplifier Output (volts)}}{\text{Diode Calib. (A/W) Diode Load } (R_L) \times \text{Video Gain(G)} \times \text{Aperture Area} (\text{mm}^2)}$$

Once this power is known, a calibrated attenuation is placed in the beam to reduce the power to the required calibration level (20 nanowatts/.8mm^2). The receiver portion of the standardized rangefinder is calibrated next by removing the detector preamplifier and video amplifier from the LRF and placing the avalanche photodiode detector (area .8mm^2) in the calibrated beam and adjusting the detector high voltage until a given video amplifier output pulse is obtained. The detector high voltage and video amplifier output ($V/_{nw}$) are recorded.

This procedure calibrates the detector preamplifier/video amplifier for a known fixed detector high voltage. It is only necessary now to reassemble the detector preamplifier and video amplifier into the LRF. The transmission loss of the optics assembly must then be factored in to provide a fully calibrated LRF at a given detector high voltage.

2.4 LASER RANGEFINDER MOUNT MT-4880( )/GVS-5(V)

2.4.1 Configuration

Paragraph 2.1 pp 2-1 thru 2-40 of Volume IV of the Design Plan describes the design configuration of the Az-El Head and discusses its interfaces with the Laser Rangefinder and the Night Vision Devices.

This description of the design configuration is correct except that only the azimuth scale reading is magnified. Figure 2-1 of the Design Plan is updated by Figure 2-29 of this document.

2.4.1.1 Mechanical Design

Paragraph 2.1.1 of Volume IV of the Design Plan discusses the five major physical elements of the Az-El Head and their major functional characteristics. That discussion of the mechanial design is correct except for two instances:

(1) The elevation drive is described as "a 64 tooth spur gear and a spring gear and a spring loaded, single lead worm gear." This sentence should read: "The elevation drive consists of a 90 degree sector of a 192 tooth helical gear and a spring-loaded, triple lead, worm gear."

(2) Five non-coherent fiber optic bundles are used rather than the four indicated.

2.4.1.2 Azimuth Drive

The Azimuth Drive is essentially that used in the GVS-3 Adapter Mount. The modifications to this drive and its detailed description are given correctly in paragraph 2.1.2, Volume IV, of the Design Plan. The azimuth angle readout is quite different from that used in the GVS-3, but is accurately detailed in the Design Plan except that a 1.5 x magnifying lens is used rather than the 2X as stated. Figure 2-4 of the Design Plan is replaced by Figure 2-30 of this report.

2.4.1.3 Elevation Drive

The elevation drive described and discussed in paragraph 2.1.3, Volume IV, of the Design Plan was fabricated, assembled, and tested. One change was made at that time: material for the elevation drive casting was changed from Vanosil to 356 - T6 aluminum alloy for three reasons. First, the number of available sources for both the Vanosil ingot and the casting was very small. Second, the number of available machining facilities was very small.

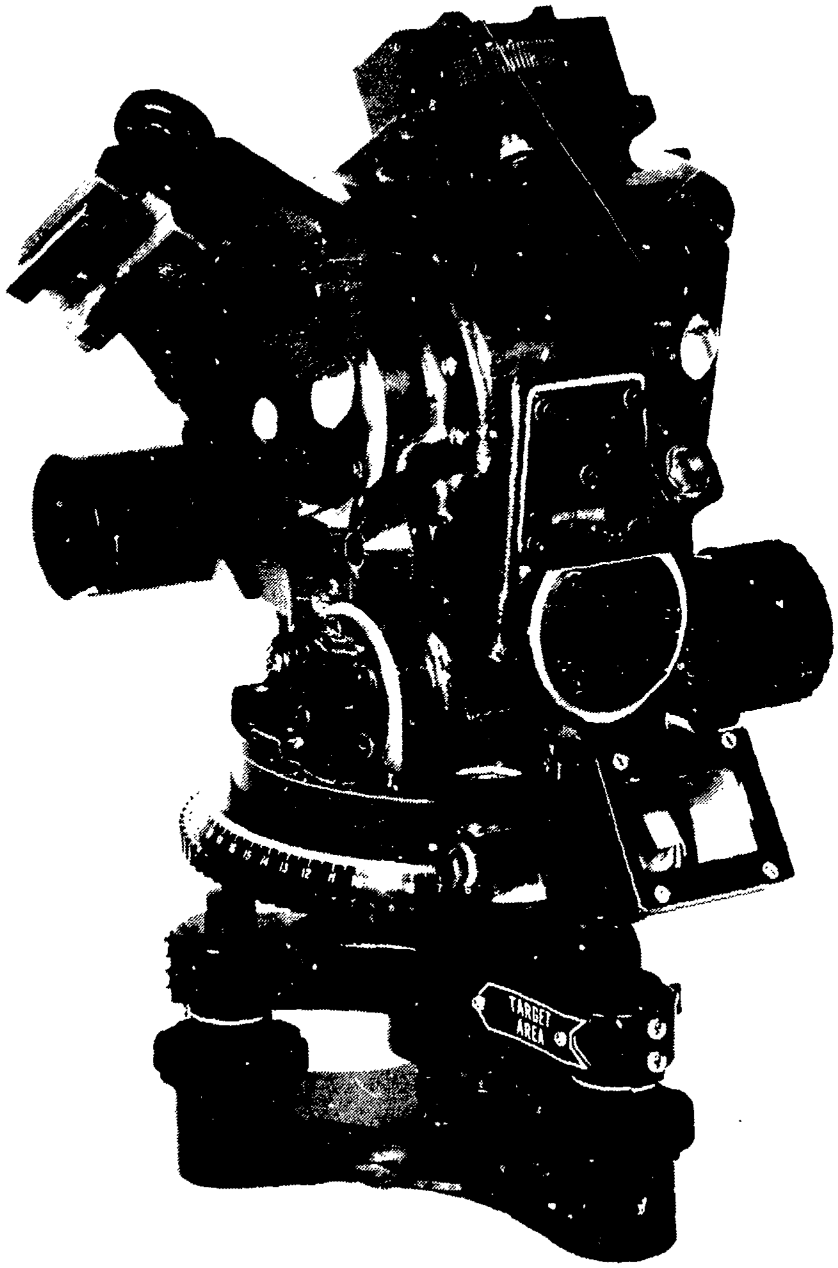


Figure 2-29. Laser Rangefinder Mount MT-4880( ) GVS-5

8	7	6	5	4

NOTE
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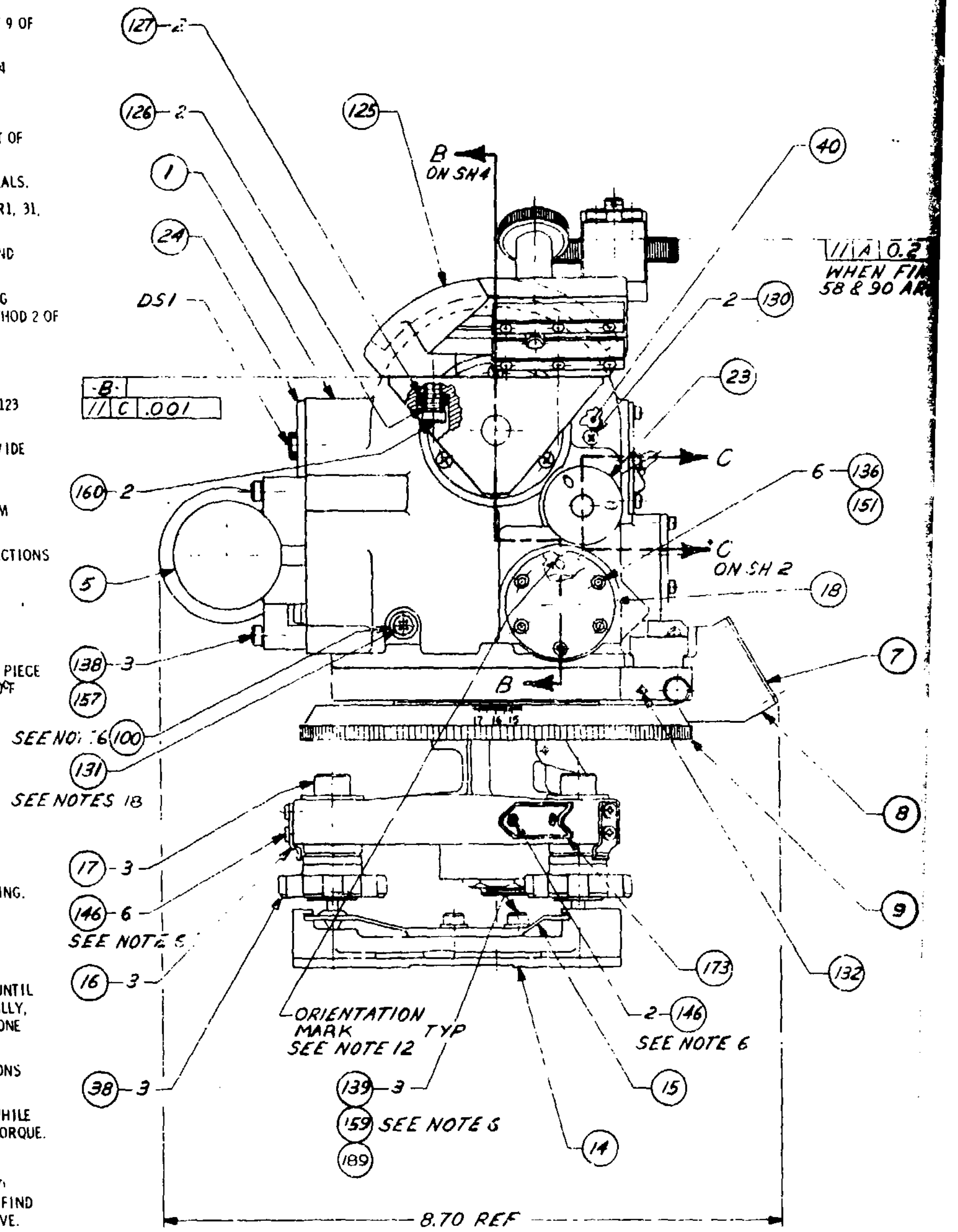
NOTES:

1. WORKMANSHIP SHALL BE IN ACCORDANCE WITH REQUIREMENT 9 OF MIL-STD-454.
2. SOLDER ALL CONNECTIONS PER REQUIREMENT 5 OF MIL-STD-454 USING FIND NO. 185.
3. DIMENSIONS AND TOLERANCES PER ANSI Y14.5.
4. SPRING, SPACER, ECCENTRIC BEARING AND PINION ARE PART OF FIND NO. 29.
5. APPLY A THIN COAT OF FIND NO. 184 TO ALL "O" RINGS AND SEALS.
6. PRIOR TO ASSEMBLY, COAT THE THREADS OF FIND NO'S. FL1, R1, 31, 100, 145, 146, 150, 82 AND 159 WITH FIND NO. 178.
7. ADJUST FIND NO. 83 FOR A .002 TO .003 INCH GAP BETWEEN FIND NO. 83 AND FIND NO. 86.
8. PRIOR TO ASSEMBLY, COAT SHAFT OF FIND NO. 10 AND MATING SURFACE OF FIND NO'S. 26 AND 77 WITH FIND NO. 182 PER METHOD 2 OF MIL-STD-1450.
9. AFTER ADJUSTING FIND NO. 83, FILL SLOT IN FIND NO. 83 AND THREADS OPPOSING SLOTS WITH FIND NO. 181.
10. REMOVE NECESSARY LAMINATIONS FROM FIND NO'S 115 AND 123 TO ESTABLISH .094 $\pm$ .005 DIMENSIONS SHOWN.
11. FIND NO. 56 TO BE STAKED ABOVE DIMENSION SHOWN TO PROVIDE CLEARANCE FOR FIND NO. 94.
12. INSTALL FIND NO'S. 104 AND 118 WITH ORIENTATION MARK IN POSITION SHOWN THEN ROTATE CLOCKWISE UNTIL MINIMUM BACKLASH BETWEEN FIND NO. 92 AND 114 IS OBTAINED.
13. BOND LEADS OF FIND NO. 56 INTO FIND NO. 1 AS SHOWN IN SECTIONS G-G AND H-H USING FIND NO. 179.
14. STAKE ALL WIRING AND LEADS OF FIND NO. 56 TO FIND NO. 1 (APPROXIMATELY EVERY .50 INCHES) USING FIND NO. 181.
15. SEAL HOLE IN FIND NO. 5 AS SHOWN USING FIND NO. 179.
16. SLEEVE LEADS OF FL1, R2, E2, E1, DS1 AND R1 USING A .38/.50 PIECE OF FIND NO. 177. SHRINK USING NON FLAMMABLE HEAT OF 230°F MAX FOR 30 SECONDS MAX.
17. SIMULTANEOUSLY ADJUST ECCENTRIC BEARING OF FIND NO. 29 UNTIL MINIMUM BACKLASH BETWEEN FIND NO. 36 AND 77 IS OBTAINED.
18. PRESSURE TEST AT 12 + 0.5 PSIG. LEAK RATE TO BE ZERO FOR 3 HOURS. AFTER PRESSURE TESTING, REMOVE BOTH SEAL SCREWS, FIND NO. 131, AND FLUSH WITH FIND NO. 180 AT 5 PSIG FOR APPROXIMATELY 10 MINUTES. REPLACE BOTH SEAL SCREWS IMMEDIATELY AFTER FLUSHING.
19. VENDOR ITEM SEE SPECIFICATION OR SOURCE CONTROL DRAWING.
20. BOND FIND NO'S. 54 AND 55 TO FIND NO. 1, AS SHOWN USING FIND NO. 179.
21. BOND FIND NO. 41 TO FIND NO. 24 USING FIND NO. 179.
22. WITH FIND NO'S. 87 AND 114 REMOVED, TIGHTEN FIND NO. 49 UNTIL THE WORM ASSEMBLY JUST REMAINS SUSPENDED, HORIZONTALLY, FROM ITS OWN WEIGHT. NEXT, LOOSEN FIND NO. 49 BETWEEN ONE AND TWO DEGREES.
23. HUBS FIND NO. 2 AND FIND NO. 4 TO BE LOCATED TO DIMENSIONS SHOWN ON SHEET 2 PRIOR TO PINNING.
24. WITH THE BASE FIND NO. 14 CLAMPED, TIGHTEN FIND NO. 70 WHILE ROTATING FIND NO. 125. ADJUST TO 20 $\pm$ 2 IN-LBS RUNNING TORQUE.
25. BOND FIND NO. 28 TO FIND NO. 5 USING FIND NO. 179.
26. STRIP INSULATION AS SHOWN; SOLDER STRANDS OF STRIPPED SECTION USING FIND NO. 185; FILL GROOVE TO SURFACE WITH FIND NO. 187 ASSURING .03 MIN. CLEARANCE CONDUCTOR TO GROOVE.



REVISION STATUS WHERE MORE THAN ONE SHEET

SH	REV	SH	REV
1	B	4	B
2	B	5	A
3	B		

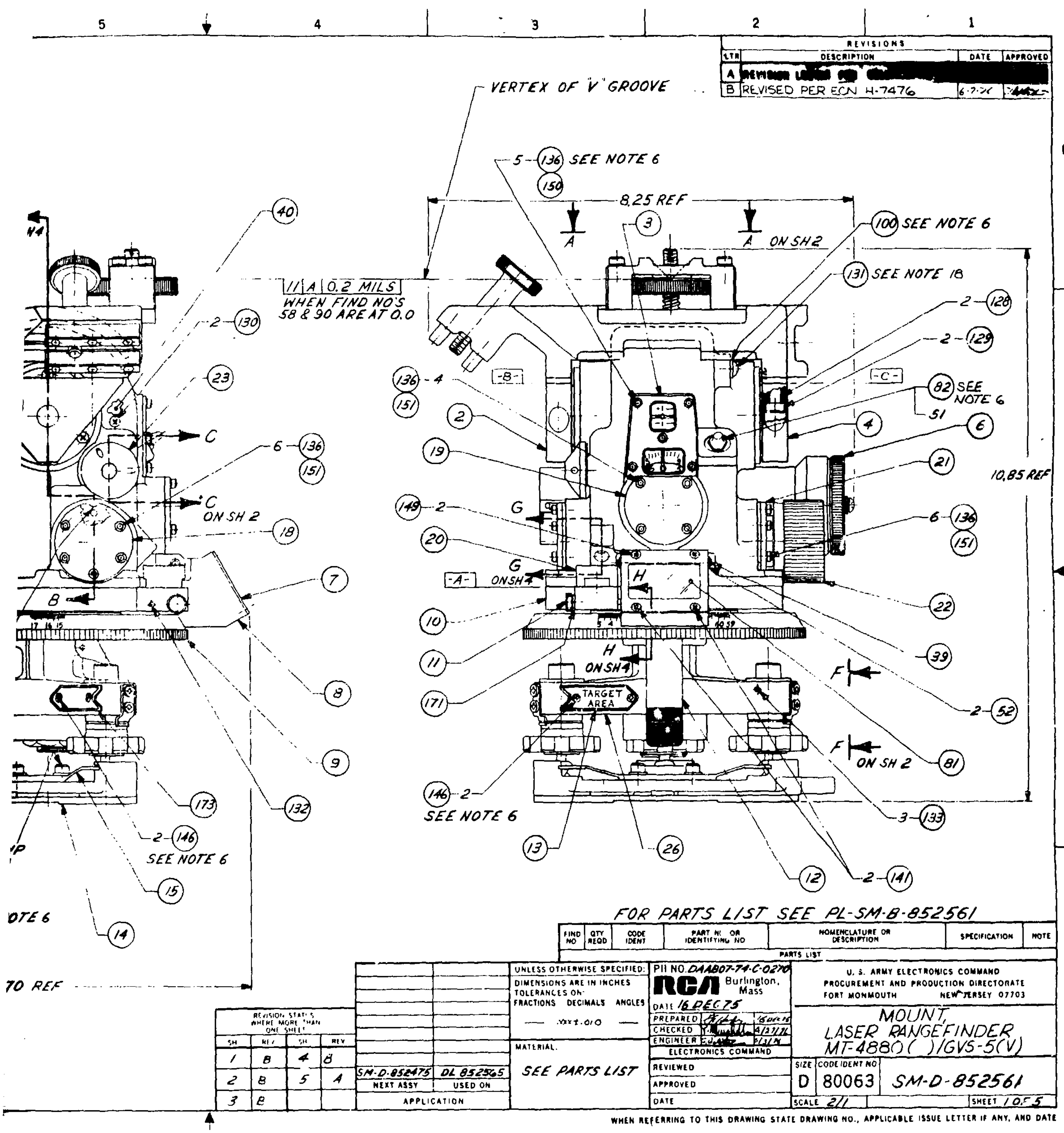


Figure 2-30. Az-EL Head Configuration (Sheet 1 of 4)

NOTE
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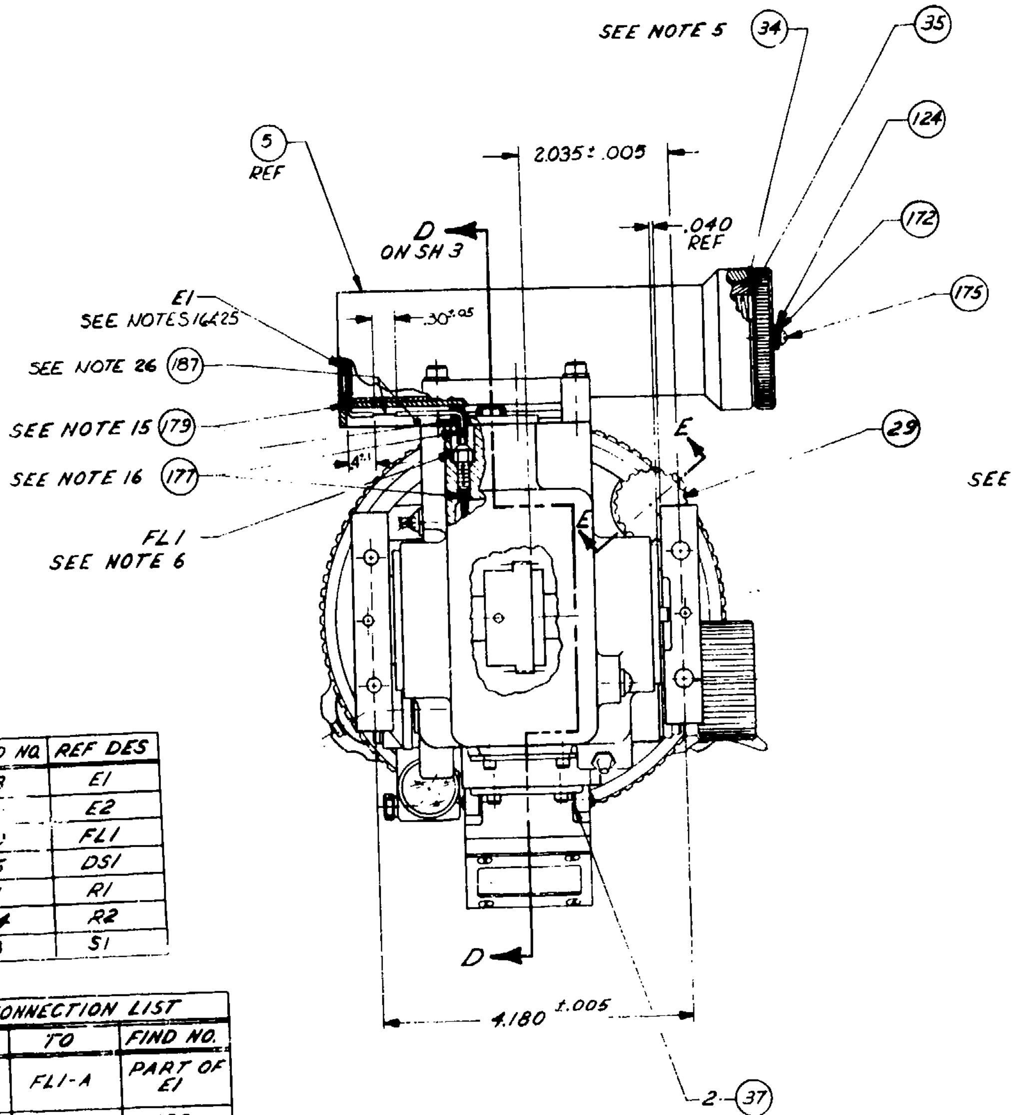
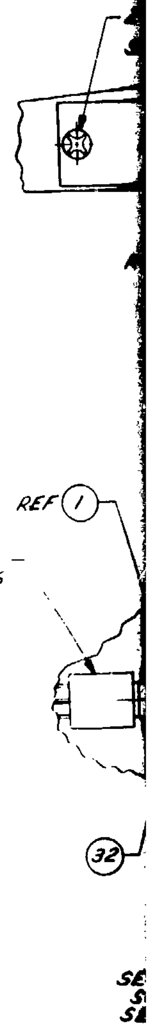
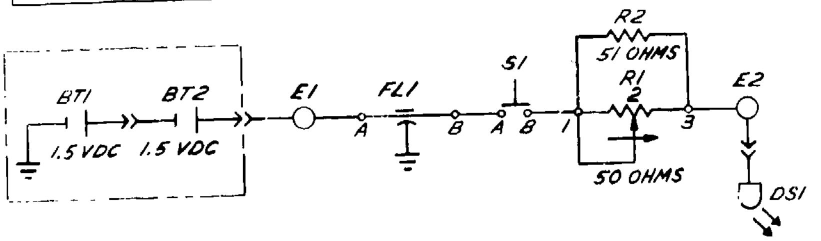


VIEW A-A
FIND NO. 125 REMOVED
SEE SHEET 1



FIND NO.	REF DES
28	E1
[illegible]	E2
[illegible]	FL1
25	DS1
61	R1
174	R2
113	S1

WIRE CONNECTION LIST		
FROM	TO	FIND NO.
E1	FL1-A	PART OF E1
FL1-B	S1-A	183
S1-B	R1-1	183
R1-1	R1-3	R2
R1-3	E2	183
R1-1	R1-2	186



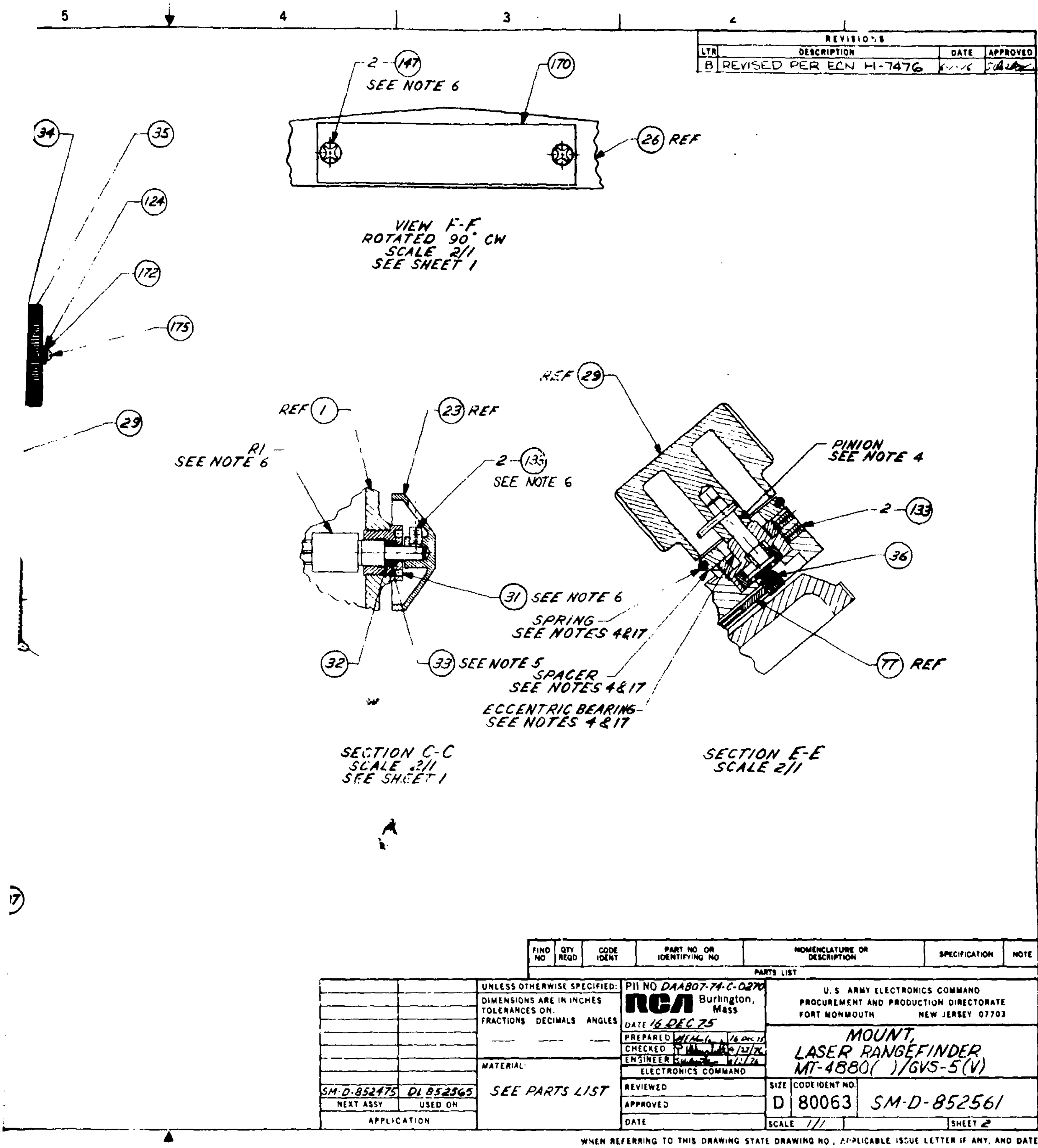
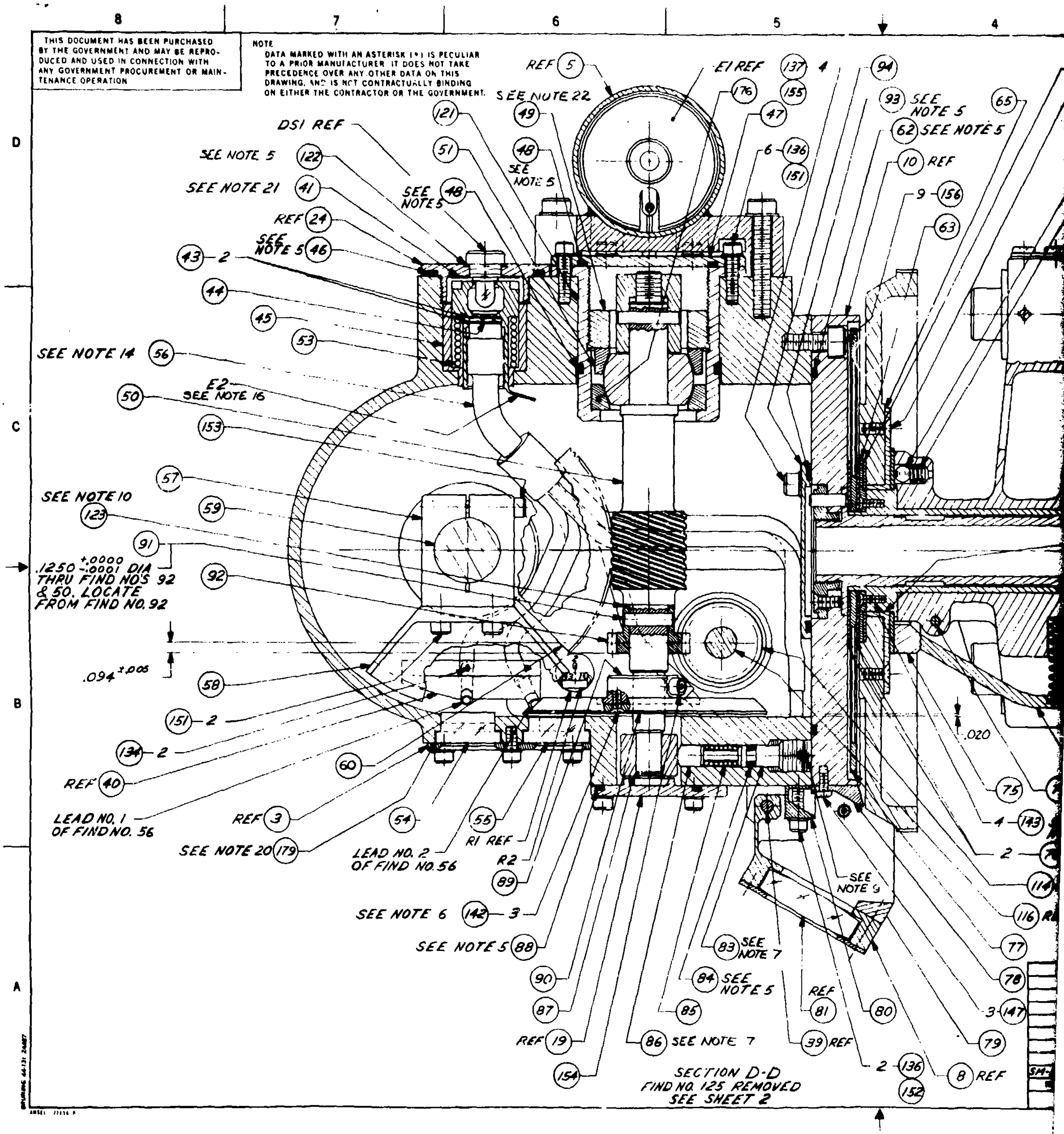


Figure 2-30. Az-El Head Configuration (Sheet 2 of 4)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NOTE
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SEE NOTE 22
DSI REF
SEE NOTE 5
SEE NOTE 21
SEE NOTE 14
E2 SEE NOTE 16
SEE NOTE 10
.1250 +.0000 -.0001 DIA THRU FIND NO'S 92 & 50. LOCATE FROM FIND NO. 92
.094 ±.005
LEAD NO. 1 OF FIND NO. 56
SEE NOTE 20
LEAD NO. 2 OF FIND NO. 56
R1 REF
R2
SEE NOTE 6
SEE NOTE 7
SEE NOTE 9
.020
SECTION D-D
FIND NO. 125 REMOVED
SEE SHEET 2

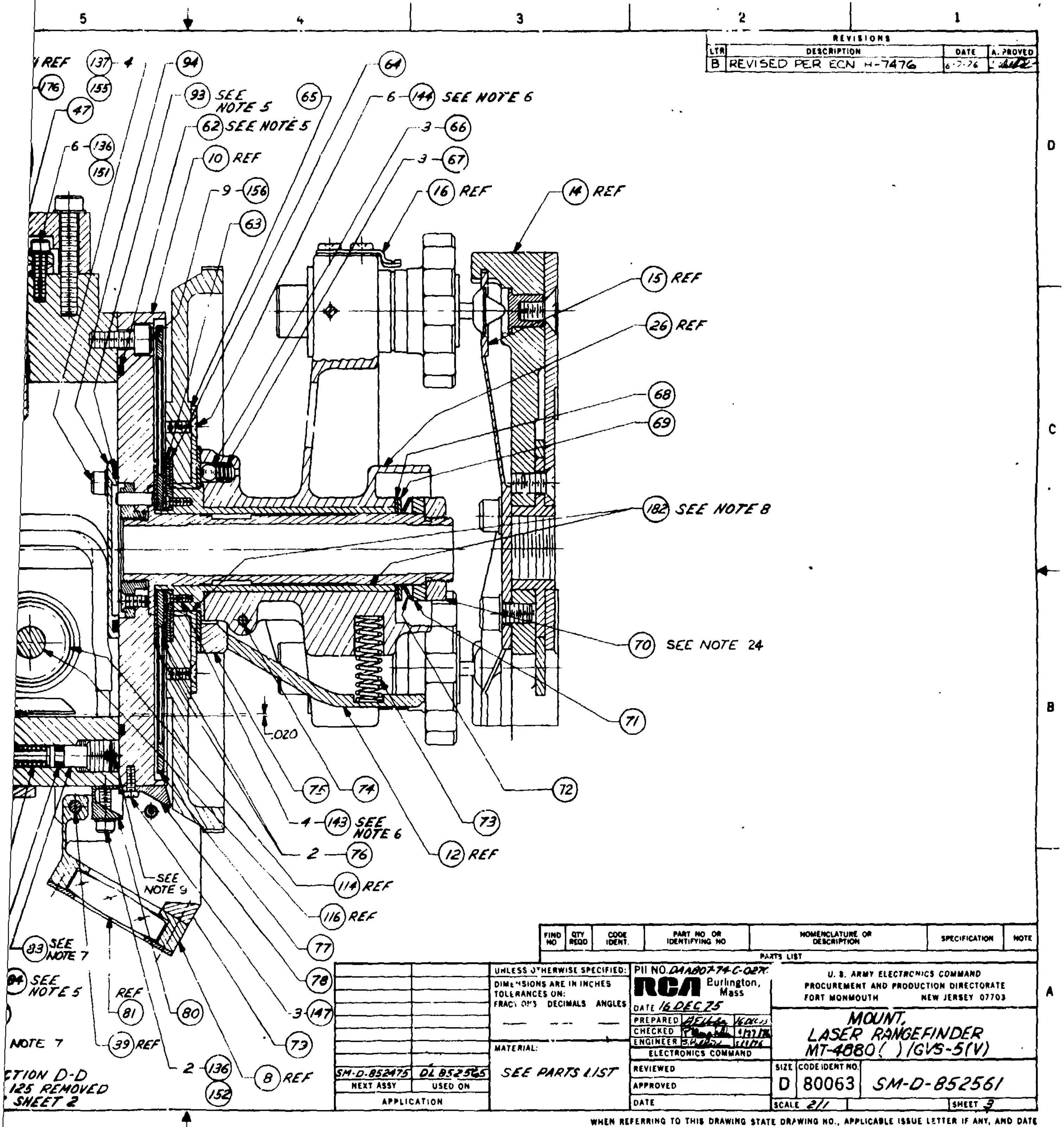

Figure 2-30. Az-EL Head Configuration (Sheet 3 of 4)

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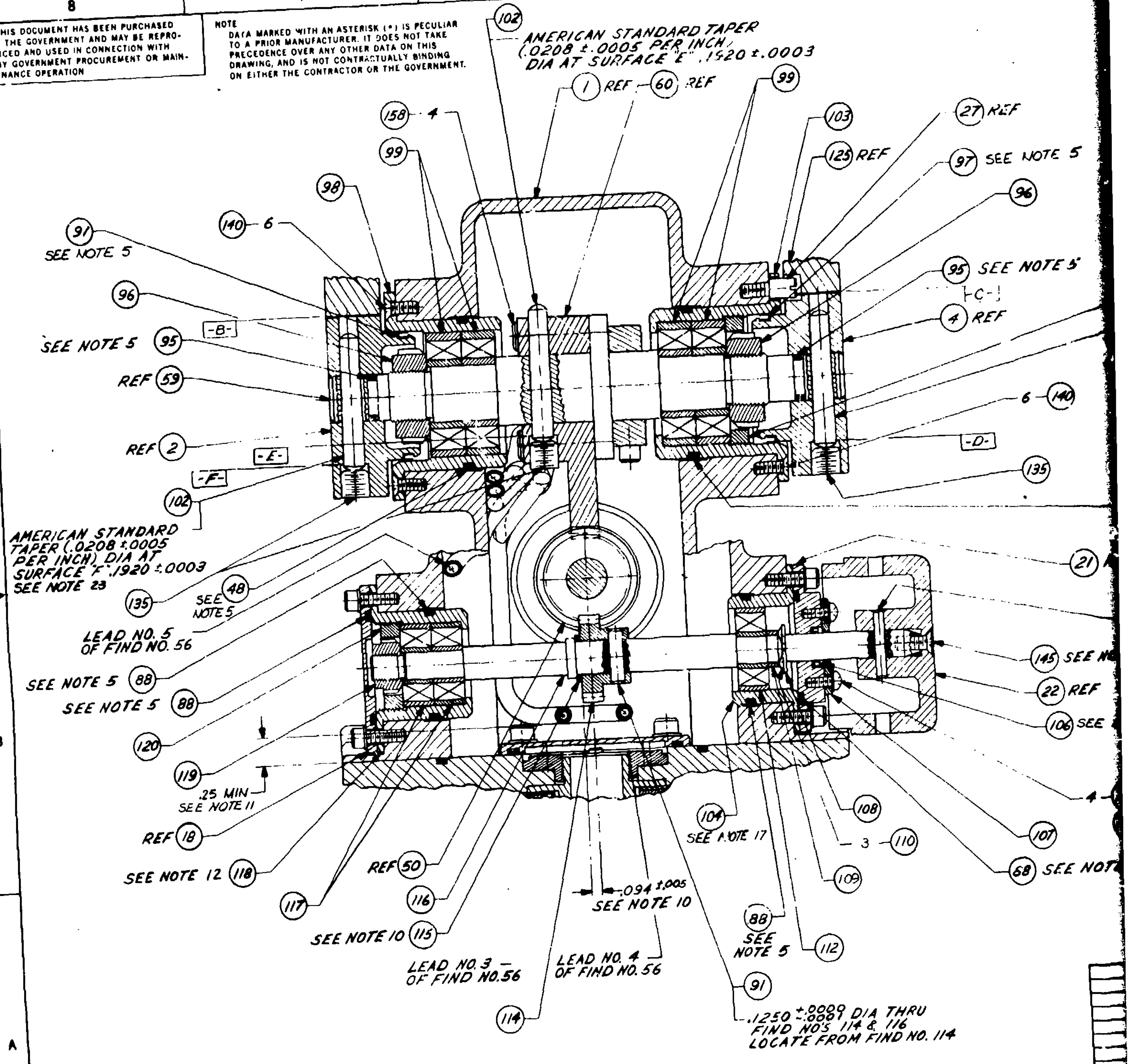


SECTION B-B
SEE SHEET 1

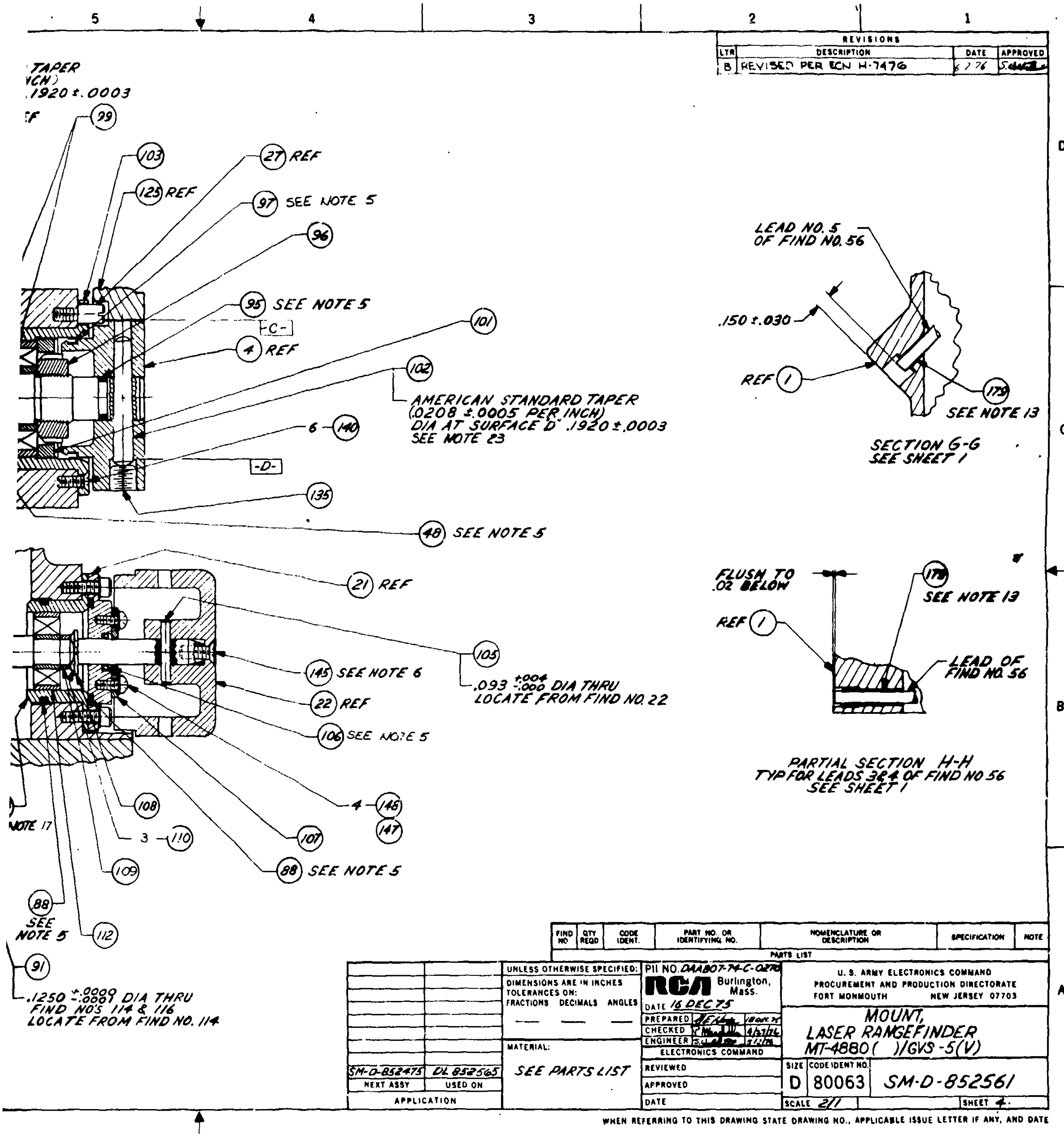


Figure 2-30. Az-El Head Configuration
(Sheet 4 of 4)

Third, the cost for machining the casting was prohibitive. Because of the larger coefficient of expansion of the new alloy, some clearances between sleeves and casting bores were increased. The error budget (Table 3-2 of the Design Plan) was revised to reflect these changes and shows a worst case error of 5.54 mr against a requirement of 5.0 mr. This is an arithmetic addition of seven error sources - all maximized and in the same direction. The RMS value of these sources is 2.76 mr. The increase is due solely to differential expansion along the worm shaft. It was considered that the probability of all sources being at maximum in the same direction is sufficiently low for the material change to be acceptable.

When the elevation drive was assembled as designed, it did not perform properly. When the worm was spring-loaded against the spur gear, the drive would bind so that excessive torque was required for rotation. Initially, it appeared that the problem was due to a twisting moment applied to the spur gear. When spring loaded into the spur gear, the worm is in two-point contact with the spur gear. One point is near one edge of the face of the driven tooth of the spur gear; the other point is near the opposite edge of the trailing face of the next tooth. Since these forces are in opposite directions and are separated by about 0.160 inches, a twisting moment is generated.

A new worm and helical gear were fabricated on the premise that the moment arm with this design would be reduced from 0.160 to about 0.020 inches and reduce the binding to insignificance.

However, the performance of this set was essentially the same as that of the spur and worm, i.e., excessive input torque was required when the mesh was spring-loaded. In addition, when operated without a spring load, but on fixed centers, it was found that the drive was smooth when operating with a resisting moment load, but jittered or chattered when operating with an 'aiding' moment load.

The total problem of improper operation either with or without spring loading was then the subject of considerable re-evaluation and test. Two sets of commercial steel-on-bronze worm and wheel gears were purchased and sequentially assembled into a unit. The first set comprised a 72 tooth, 24 D. P., phosphor bronze worm gear in mesh with a single start worm having a lead angle of 4.75 degrees. The second set comprised a 72 tooth, 24 D. P., phosphor bronze worm gear in mesh with a double start worm having a lead angle of 9.5 degrees. These gear sets operated with a light spring load and without chatter.

In parallel with these tests, the performance of the spur and helical gear sets was discussed with RCA's consultant, Eliot Buckingham, with Richard Will, Chief Engineer at the Delroyd Worm Gear Division of Delaval Turbine, and with several other people cognizant of worm drives. The consensus was that the lead angle was the single largest contributor to the problem by virtue of its effect on self-locking characteristics. The initial lead angle was 2.8 degrees which is well below the probable static friction angle: The static friction angle for a coefficient of friction of 0.15 is 8.5 degrees. The coefficient of friction and, therefore, the friction angle decrease when "running" to about 2 to 3 degrees. It was believed that with an "aiding" moment load the back-driving-efficiency changes from plus the minus due to friction torque decreasing with speed and thus chatter occurs. This is equivalent to negative feedback producing oscillation in a servo system. It was considered that the low lead angle was causing excessive torque in a spring-loaded mesh in a similar, but less-well-understood manner.

Another set of gears was fabricated with the lead angle increased to 5.5 degrees, with a 20 degree pressure angle rather than 14.5 degrees and with a considerably smaller worm pitch radius. The reasons for the increased pressure angle were: (1) to promote greater separating forces between the gears, and (2) to provide a tooth form which would be less likely to wedge when spring loaded. Because of an increase in its outer diameter, the gear was changed from a 64-tooth 24 D. P. gear to a 90 degree sector of a 192-tooth 64 D. P. gear. The worm was changed from a single lead to a triple lead. It was decided to retain the helical tooth form for the gear to preclude additional problems, although there is no reason to suspect additional problems with the use of a spur gear.

All references to the "spur" gear in the Design Plan, Volume IV, should become "helical" gear with the change discussed above.

The 1:1 crossed helical gear drive used between the elevation input shaft and the worm shaft has been changed to a 0.6:1 ratio. The reason for the change is to reduce the input torque on the elevation drive knob by a like ratio. Figure 2-4 of the Design Plan is replaced by Figure 2-30 of this report.

2.4.1.3.1 Elevation Angle Readout

In paragraph 2.1.3.2, Volume IV, of the Design Plan it is stated that prior to engraving, the surface to be engraved is painted white with an overcoat of black or green paint. In the current design, an overcoat of black is applied over the white on all surfaces to be engraved. A cost of red paint is then applied, over the black, on those surfaces used for indication of positive rotation and then the surfaces are engraved.

This change was made to improve contrast by increasing opacity of the red surface. The green was changed to red to improve daylight contrast of background to engraved character.

2.4.1.4 Leveling Screw/Spring

The leveling screw assembly is identical to that used on the GVS-3 Adapter Mount except for use of a harder material for the screw itself. The reasoning and analysis are discussed in paragraph 3.2.4 of Volume IV of the Design Plan. The Leveling Screw/Spring design has been changed significantly from the GVS-3 design. The new design is presented and discussed in paragraph 2.1.4 of the Design Plan.

2.4.1.5 Fiber Optics Illuminator

A Fiber Optics Illuminator is used to transmit light from the single source (incandescent bulb) to the four points of illumination.

The description of the Fiber Optics Illuminator as written in paragraph 2.1.5 of Volume IV of the Design Plan is accurate except for some minor aspects discussed in the paragraph below.

In paragraph 2.1.5.1 (2) (F) of Volume IV of the Design Plan, the number of bundles is listed as four. The number used is five. The reason is that two bundles are used to illuminate the azimuth indicator since this requires front illumination of a relatively large area.

In paragraph 2.1.5.1 (4) of the Design Plan the magnifier is listed as "One: 2X." This has been changed to "One: 1.5X." The reason was to accommodate a combination of available glass, operator viewing distance, distance of magnifier from object, and curvature of object.

Because of the change in number of fiber bundles from four to five, certain luminescence and radiance values in the Design Plan will be reduced by 20 percent. These are listed in Table 2-2.

Table 2-2. Reduction in Luminescence and Radiance Values

Design Plan Paragraph	Reference	Design Plan Number	Corrected Number
2.1.5.2.1	Luminescence of longest bundle	0.0295	0.0236
2.1.5.2.1	Radiance, at pertinent bundle	0.0295	0.0236
2.1.5.2.1	B_F	2.9205×10^{-1}	2.336×10^{-2}
2.1.5.2.2	B	0.0376	0.030
2.1.5.2.2	Luminescence of 6 inch fiber	0.0297	0.0238

2.4.1.6 Power Source

The power source for the Az-El Head is a pair of 1.5 V Alkaline D-cell. The description of the Power Source as written in paragraph 2.1.6 of Volume IV of the Design Plan is correct.

2.4.2 Modified Tripod

2.4.2.1 Modifications

The tripod used in the Az-El Head Set is that designed for the GVS-3 except for some minor changes. These tripod modifications are discussed in paragraph 2.2 of Volume IV of the Design Plan and are accurate except for a typographical error: "G.C." should read "C.G."

2.4.2.2 Tripod Interface

As written in paragraph 2.2.1 of Volume IV of the Design Plan, the Tripod Interface is correct.

2.4.3 Accessories

2.4.3.1 Carrying Case

The final design of the carrying case is shown in Figure 2-31. It contains all of the features listed in paragraph 5.1.2 of Volume IV pp 5-1 thru 5-2 of the design plan and differs only in final form from Figure 5.1 of the design plan.

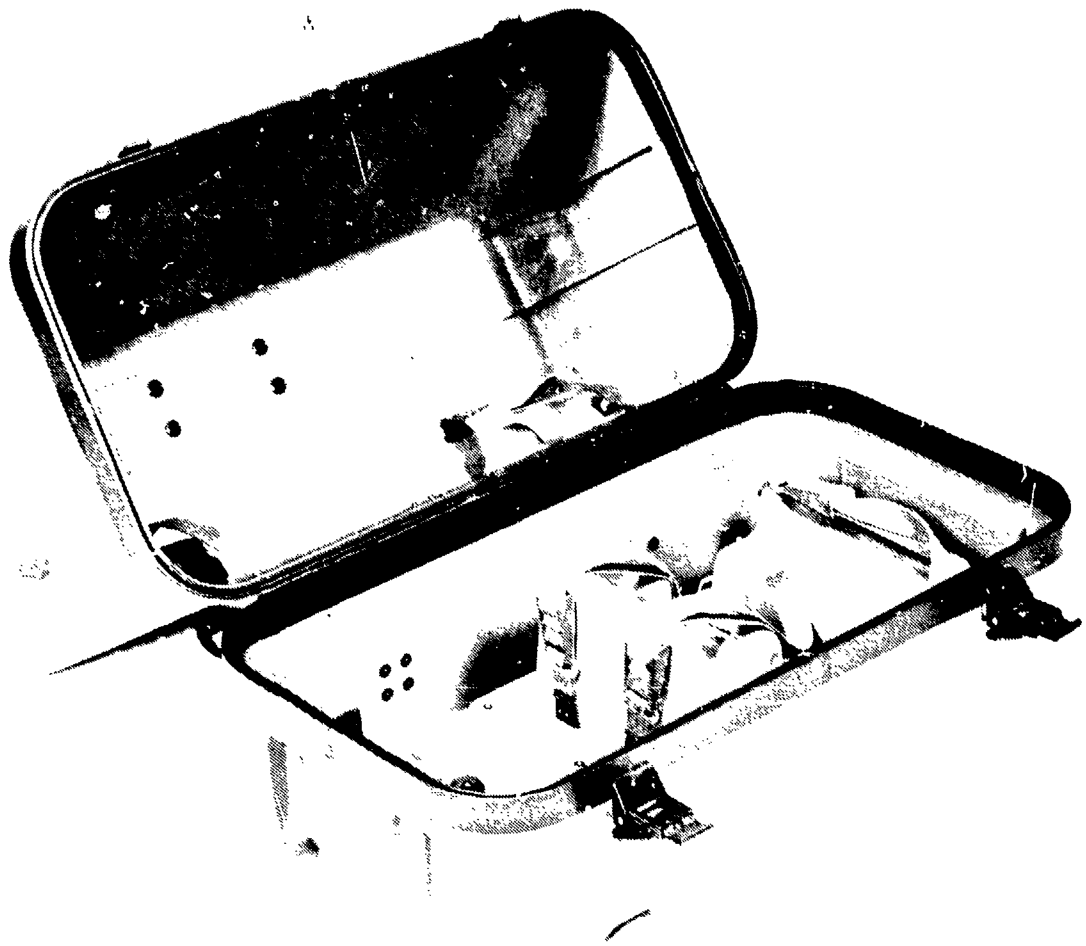


Figure 2-31. Az-El Head Carrying Case

The form factor differences were made to accommodate the fabrication processes associated with the material chosen for the carrying case: A.B.S. (Acrylonitrile Butadiene Styrene).

The final design of the second case, a canvas carrying case, is shown in Figure 2-32, it can accommodate the AEH shelf mount and one battery.

2.4.3.2 Transit Case

The final design of the transit case is shown in Figure 2-33 and contains all of the features and provisions listed in Paragraphs 5.2.1 and 5.2.2 pp 5-3 thru 5-5 of Volume IV of the Design Plan. It differs only in final form factor from Figure 5.3 of the Design Plan. The changes to the form factor were made to accommodate the differences in the carrying case design.

The transit case successfully passed all of the environmental tests listed on page 5-4 of Volume IV of the Design Plan, however, minor evidence of corrosion was traced to an incompatibility of materials and its mounting hardware, and all of the hardware will be replaced.

2.4.3.3 Adapter Bracket

The adapter bracket is used to mount the HHLR to the Az-El Head when the HHLR is used in conjunction with the Night Vision Device. The adapter is accurately described in paragraph 5.3 of Volume IV of the Design Plan.

2.4.4 Design Analyses

2.4.4.1 Transmission Error Analysis

Paragraph 2.4.1.3 of this report discusses the change in elevation drive from a worm and spur gear mesh to a worm and helical gear mesh and the reasons therefor.

In addition, in paragraph 2.4.1.3 of this report, there is a discussion of the change in aluminum alloy used for the elevation drive casting. There is an effect, due to this change in material, on one of the error sources listed in Table 3-1, Angular Transmission Error, of Volume IV of the Design Plan: Differential expansion along the worm shaft. The magnitude of this error source increases from ± 0.17 mr to $\pm$ 1.01 mr at the temperature extremes. When this change is incorporated into Table 3-2 of Volume IV of the design Plan, the total Maximum Angular Error changes as shown below:

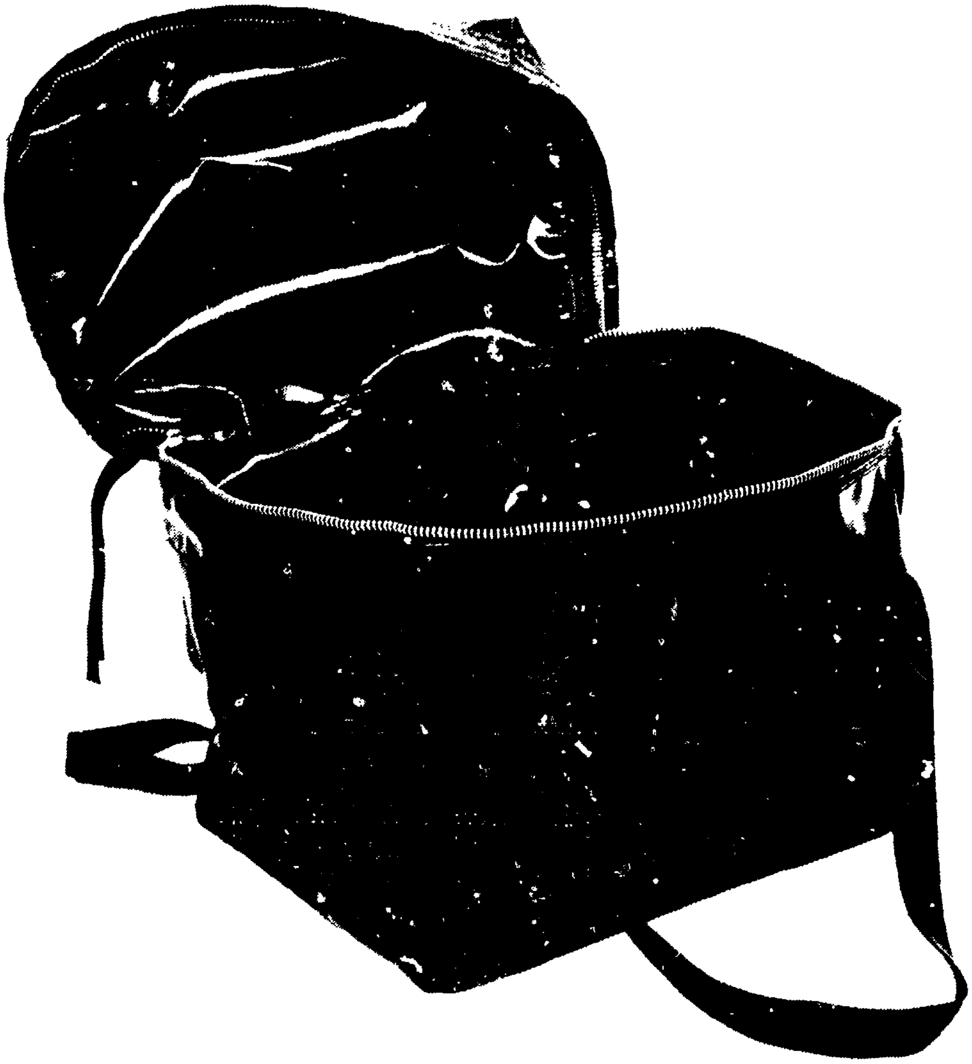


Figure 2-32. Az-El Head Canvas Carrying Case

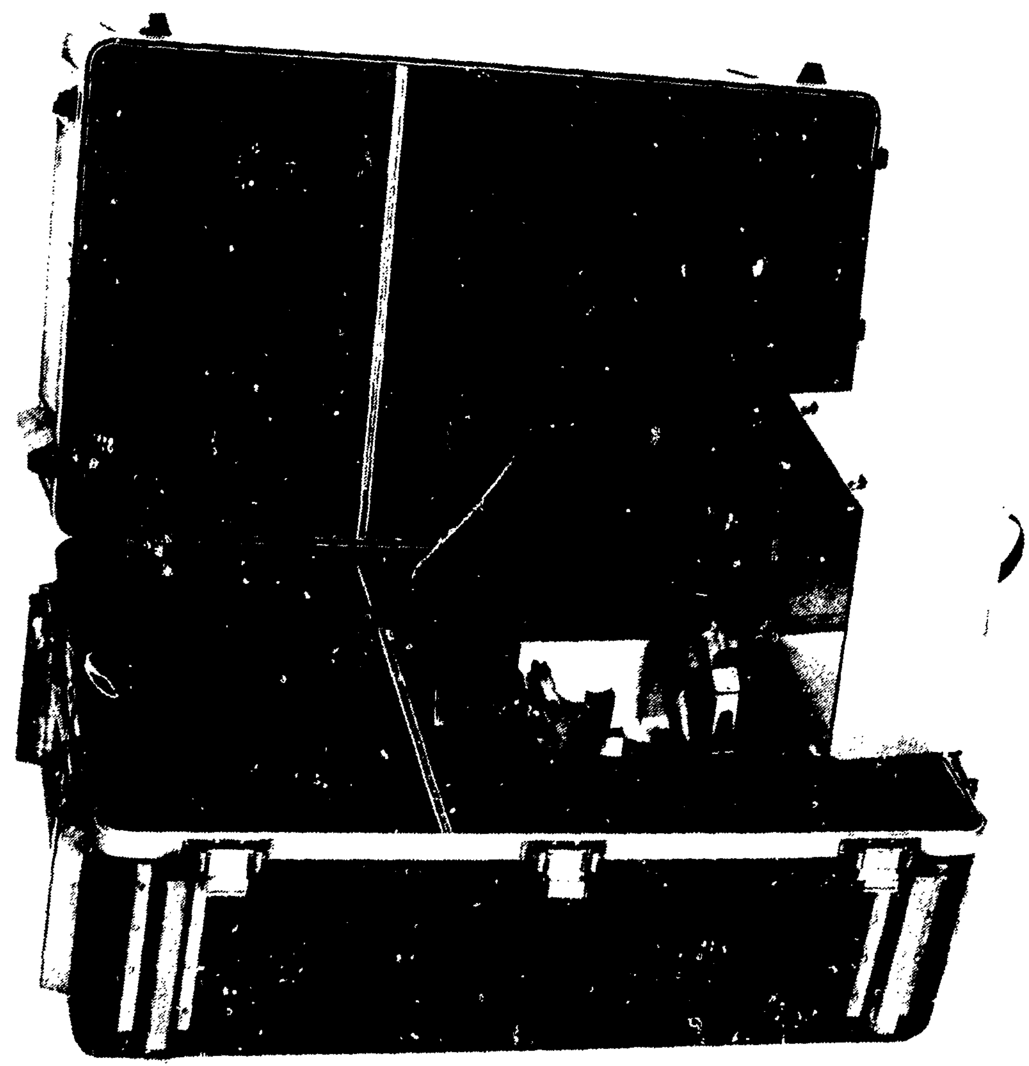


Figure 2-33. Az-El Head Transit Case

	Total (mr)	
	Arithmetic	RMS
As shown in Design Plan	4.70	2.10
Corrected for new alloy	5.54	2.76

Similarly Table 3-2 changes as shown below:

		Total (mr)
	Arithmetic	RMS
As shown in Design Plan	6.93	2.56
Corrected for new alloy	7.77	3.13

2.4.4.2 Thermal Analysis

The elevation housing alloy change produced a change in the calculated Δd, change in bore of the steel sleeves, for both the R-4 and the R-8 bearings. These changes are tabulated below relative to the values shown in paragraph 3.3.1 of Volume IV of the Design Plan.

	Δd (inches)	
	R-8 bearing	R-4 bearing
As shown in Design Plan	2.78×10^{-4}	2.14×10^{-4}
Corrected for new alloy	6.82×10^{-4}	5.26×10^{-4}

To accommodate these additional decreases in bore of the sleeves, their basic dimensions were increased by 3×10^{-4} inches.

2.4.5 Weight

The actual weights of two Az-El Heads are tabulated below:

Serial number 00004	11.06 pounds (with batteries)
Serial number 00005	11.12 pounds (with batteries)
Adapter	1.22 pounds

SECTION 3

TEST AND DEMONSTRATION SUMMARY

3.1 LASER RANGEFINDER SET TESTS

The "one time" environmental, EMI and nuclear tests of the AN/GVS-5 were conducted in accordance with plans submitted as required by contract. The test results were reported in contract documents. Test conducted on each unit conformed to RCA prepared "Performance Test Procedure Hand-Held Laser Rangefinder, PTP-A".

3.1.1 Summary of Performance Tests

3.1.1.1 Laboratory Tests

Data recorded in the laboratory testing of the twenty deliverable rangefinders is summarized below.

(1) Transmitter

(a)	Full beam energy	13.4 mj. ave.	(±1.5 dB)
(b)	One milliradian beam energy	12 mj. ave.	(±1.5 dB)
(c)	Percent of total energy in 1 mr.	89% ave.	(±9%
(d)	Pulse width	6.5 ns. ave.	(±0.5 ns)

(2) Boresight, Laser to Sight — 0.11 mr. ave (±0.09 mr.)

(3) Range Error — 0.7 meter ave. (30 ranges per unit)

(a)	Percentage of readings 0 error	88%
(b)	Percentage of readings +10 meters	3%
(c)	Percentage of readings -10 meters	9%

(4) False Alarms

(a)	In 100 readings at 9980 m.	0
(b)	In 2000 readings (20 x 100)	0

3.1.1.2 Extinction Tests

A number of HHLR units were tested against a target of estimated 50% diffuse reflectivity at 1745 meters with a 35 dB attenuating filter covering the transmitter aperture and the receiver stopped down by an adjustable iris diaphragm to provide additonal attenuation.

Total attenuation under good visibility conditions varied from 38 dB to 43 dB for 50% probability of detection. Calculated receiver sensitivity <u>assuming no atmospheric attenuation is as follows</u>:

(1) 50% Probability of detection

(a)	Worst	1.5×10^{-9} w/cm$^2 \cong 15 \times 10^{-9}$ w
(b)	Best	4.8×10^{-10} w/cm$^2 \cong 4.8 \times 10^{-9}$ w

(2) 99% Probability of Detection

(a)	Worst	2.2×10^{-9} w/cm$^2 \cong 22 \times 10^{-9}$ w
(b)	Best	6.8×10^{-10} w/cm$^2 \cong 6.8 \times 10^{-9}$ w

Assuming a "standard clear" day (23.5 Km visibility) the estimated round trip attenuation at 1.06 μm over a 1745 meter path is 1.5 dB.

3.1.2 Environmental Tests

As part of its Qualification Test requirement, the Laser Rangefinder Set was subjected to the environmental tests discussed in this paragraph. The set successfully passed all of these tests contingent on a retest, at the part level, of some items which degraded in humidity and/or salt fog tests. Corrective action was taken in all cases. The window coating deterioration did not significantly affect performance thus, is not classed a failure. However, improved coatings are being developed and will be specified after successful retest.

Table 3-1 lists the environmental tests which were performed on CLIN Model Serial Numbers 00001 and 00005. These units successfully passed Pre- and Post- Burn-in Conformance Tests and Burn-in Tests prior to the start of the environmental tests. The specific test methods and requirements and the resulting performance of the equipment are given in the sub-paragraphs. Unless specifically stated otherwise in these paragraphs, the Laser Rangefinder Set and the AN/TAS-6 Adapter Bracket were subjected to all tests.

3.1.2.1 Altitude Test

The altitude test was conducted in accordance with Method 500, Procedure I, of MIL-STD-810B. The equipment was subjected to a simulated altitude of 50,000 feet above sea level for one hour in its transit case in a storage, non-operating mode. The chamber pressure was then increased to simulate an altitude of

Table 3-1. Environmental Testing (Serial Nos. 00001 and 00005)

Specification EL-CP5100-0001A	Environmental Tests		
Design Requirement Paragraph	Model Serial Number	Test Identification	EL-CP5100-0001A Specification Test Para. Req't.
3.2.3.3	00001 00005	Burn-In	4.7.4
3.2.5.1	00005	Altitude	4.4.1
3.2.5.2	00005	Temperature (High and Low)	4.4.2 & 4.4.3
3.2.5.5	00005	Sand & Dust	4.4.6
3.2.5.3	00005	Humidity	4.4.4
3.2.5.6	00005	Salt Fog	4.4.7
3.2.5.4	00001	Immersion	4.4.5
3.2.5.8	00001	Vibration	4.4.9.1
3.2.5.8	00001	Shock	4.4.9.2
3.2.5.4	00001	Immersion	4.4.5
3.2.5.7	00001	Fungus	4.4.8

10,000 feet and an operational test performed. Neither of the Adapter Brackets was included in the equipment subjected to the Altitude Test. This test was passed with no discrepancies.

3.1.2.2 High Temperature Test

The High Temperature Test was conducted in accordance with Method 501, Procedure II of MIL-STD-810B. The unit was instrumented with thermocouples and subjected to storage temperature cycling between 120°F and 160°F for 36 hours. The chamber temperature was then maintained at 160°F and the unit operated at a rate of 96 rangings - (5 seconds each) - per hour until stabilization was reached. Then an operational test was performed. The AN/TAS-6 Adapter Bracket was not included in the High Temperature Test. This test was passed with no discrepancies.

3.1.2.3 Low Temperature Test

The low temperature test was conducted in accordance with Method 502, Procedure I, MIL-STD-810B. The unit was instrumented with thermocouples and then be subjected to a storage temperature of -70°F for a period of 2 hours following stabilization. The chamber temperature was then increased to -50°F and an operational test performed. This test was passed with no discrepancies.

3.1.2.4 Sand and Dust Test

The sand and dust test was conducted in accordance with Method 510, Procedure I of MIL-STD-810B. The unit was subjected to air velocity of 1750 feet per minute with a dust concentration of 0.3 gm per cubic feet for six hours while at a temperature of 73°F. With the dust feed stopped, the temperature was increased to 145°F and the humidity held at less than 10 percent for 16 hours. The temperature was maintained at 145°F and the dust feed started and maintained as before for six hours. A visual inspection for mechanical degradation and an operational test were performed at the conclusion of the test. No batteries were included in the Sand and Dust Test. This test was passed with no discrepancies.

3.1.2.5 Humidity Test

The humidity test was conducted in accordance with Method 507, Procedure III of MIL-STD-810B. The equipment was subjected to a 24 hour drying cycle, a 24 hour conditioning cycle, and 5 continuous 48-hour cycles with humidity maintained at 94 percent and the temperature cycling between 70°F and 150°F.

The unit was operated during each of the 48 hour cycles. The test item was opened and removed from its enclosure and subjected to a chamber temperature of 86°F and a relative humidity of 94 percent for 480 hours. At the conclusion of this period the unit was reassembled and operated. No batteries were included in the Humidity Test.

3.1.2.5.1 Failures Affecting Performance

Two failures, the only ones affecting performance, occurred during the last 20 days of the humidity test. The failures, and subsequent corrective actions, are detailed in the following paragraphs.

(1) Minimum Range Variable Resistor - SM-C-852059 - Moisture affected the minimum range circuit causing improper operation until the HHLR was dried out at the end of test. It was first assumed that moisture entered the case of the variable resistor. Since operation was normal during the first 10 days with the HHLR cover on and the assembly was still slightly pressurized prior to cover removal, there was no leakage into the resistor case through the shaft seal or into the HHLR through the panel seal, both a part of the resistor. Since the case is sealed at its assembly interface and around the terminals, the initial conclusion was that either these fixed seals were improperly made or the case was damaged.

Humidity tests were subsequently run on the variable resistor and no degradation in its performance was observed. The failure had been evidenced by the operator not being able to set in minimum ranges above approximately 2800 meters. The circuit parameters are such that a resistance as "low" as one hundred thousand ohms across the variable resistor could have caused the observed failure. The conclusion, by inference, is that moisture on the flexprint at the terminals at the range counter and across the terminals caused the circuit malfunction. The circuit did perform properly when it was dried out. Since the HHLR has a dry nitrogen internal ambient when in use, no corrective action has been taken.

(2) Q-Switch Deterioration - SM-D-85200 Assy. - The Q-Switch, a cellulose acetate disc deformed due to moisture. The Q-Switch is located in the ferrule in a cavity which is specified to be purged with dry nitrogen and sealed. A process change in which the ferrule is bonded to the laser rod by "buttering", and the fill holes are not back-filled, appeared to have caused an inadequate seal. The conclusion was that the cavity must be properly sealed.

(3) Corrective Action - The ferrule design has been changed to eliminate all holes except the purge port which is a small (0.020 inch dia.) hole that is sealed after purging. Tests made on seven laser resonator assemblies showed that a seal with a leak rate less than 1 cc/day could be obtained. One of these resonators was assembled into a cavity and tested for energy output and beam divergence. The resonator was then subjected to a 20 day humidity test at 95°F and 85 percent relative humidity. The resonator was tested after the second, fourth, sixth, eleventh, and twentieth days to determine if any degradation in performance had occurred, such as a drop in energy output and an increase in beam divergence. The test results showed little change in divergence and a small (13 percent) drop in energy output over the full test period.

The resonator was disassembled and the Q-switch was examined and showed no evidence of degradation. The conclusion is that the new sealing technique is satisfactory for the specified humidity environment.

3.1.2.5.2 Deterioration Affecting Performance

(1) Deterioration of Optical Coatings - SM-A-852072 & SM-A-852073 - The coatings on the outside of both the receiver window and the transmitter filter deteriorated. The former was almost completely gone; the latter was lifted only in spots. Most of the deterioration of the wide band coating on the window occurred during the cycling portion of the humidity test. The insides of both windows, which were exposed to humidity for the last 20 days, have no visible evidence of deterioration. Neither humidity nor salt fog resistance had been specified in the reference specifications. Further, neither of the two generally referenced specifications, MIL-C-675 and MIL-C-14806 requires either water immersion, humidity, or salt fog resistance in excess of 2 days. Although the coating deterioration did not degrade performance below specification, and is therefore not classed as a failure, the effects are of concern since they must have caused a decrease in light transmission through the window.

(2) Corrective Action - Windows with sample coatings which are specified to meet a combination of several days immersion, followed by 30 days of humidity and 2 days of salt fog, per the equipment specifications, are being obtained and will be subjected to humidity (and salt fog) tests.

(3) Deterioration of plated surface on the battery cover - The cast aluminum battery cover, SM-D-852045, is plated with rhodium over nickel and showed significant blistering under the plating after 10 days in contact with the control panel followed by 20 days of non-contact during humidity tests.

(4) Corrective Action - The metallurgical judgement was that the deterioration of the plating could only have been caused by a lack of adequate process control during the plating process. Corrective action will include test of control samples to prove adequacy of process control.

(5) White Residue - All items tested showed a white residue particularly in pockets or interfaces between parts. This is apparently a residue from the sand and dust tests (silica flour). When brushed or scraped away all areas have been free from corrosion. No corrective action is planned.

(6) Transit case corrosion - SM-D-852001 - The humidity indicator body exhibited heavy corrosion after the humidity test. The specific part may be plated brass or anodized aluminum to meet requirements of MIL-STD-171.

(7) Corrective Action:

(a) A requirement to meet Humidity (and Salt Fog) Tests was added to the Transit Case Specification.

(b) The Transit Case Specification was revised to specify an aluminum humidity indicator.

3.1.2.6 Salt Fog Test

The salt fog test was conducted in accordance with Method 509, Procedure I, of MIL-STD-810B. The test item was placed in a salt fog chamber and exposed to a 5 percent salt solution salt fog at a temperature of 95°F for 48 hours. A visual inspection was performed at the conclusion of the salt fog test.

The failure criteria for salt fog are defined in specification EL-CP5100-0001A paragraph 4 as follows: ". . . corrosion of finishes and metals only. Such corrosion shall be defined as any visible degradation of the equipment surface that can be attributed to flaky, pitted, blistered, or otherwise loosened finish or metal surface." By this definition there were several failures during the test.

It should be noted that this test was run on the same unit that had been subjected to the humidity test. These failures and the subsequent corrective action are detailed in the paragraphs below:

(1) Deterioration of plated surface on the battery cover - The plating on the battery compartment cover was lifted and there was corrosion under the plating. Corrosion apparently occurred because the battery cover had been scratched and nicked by previous mishandling and the protective coating thus removed from small sections, thereby exposing the aluminum to a corrosive environment. As discussed in paragraph 3.2.1.5, the process specified for the plating is correct.

(2) Corrective Action - Repeat the salt fog test on a new battery cover.

(3) Deterioration of optical coatings - The coatings on the windows had deteriorated during the humidity test. Although it was difficult to determine, there was probably further deterioration during the salt fog test.

(4) Corrective Action - The vendor has been contacted and is recalculating a coating system to meet the humidity and salt fog requirements. Windows with sample coatings of the new system will be retested. If satisfactory, the drawings will be corrected to incorporate these coating requirements to assure resistance to the humidity and salt fog environment.

(5) Transit case corrosion - The humidity indicator body exhibited heavy corrosion after the salt fog test. The specified part may be plated brass or anodized aluminum to meet requirements of MIL-STD-171.

(6) Corrective Action -

(a) A requirement to meet the Salt Fog Test was added to the Transit Case Specification.

(b) The Transit Case Specification was revised to specify an aluminum humidity indicator.

(c) An aluminum humidity indicator will be tested separately to verify its performance in salt fog.

(7) Adapter Brackets

(a) Corrosion on mounting screws.

Rust occurred on these and some other black oxide coated parts. It was almost certainly caused by parts having been improperly coated by the vendor since similarly specified parts exhibited no corrosion.

(b) Corrosion of the mounting level mechanism of the AN/TAS-6 Adapter Bracket. Corrosion occurred at the entrance of the bore for the locking cylinder and the locking mechanism was difficult to operate.

(c) Rust appeared on cadmium plated lock-washers.

(8) Correction Action -

(a) Non required.

(b) The design of the entrance port area was revised from a sharp to a rounded edge and a dry film lubricant was specified for sliding surfaces at assembly.

(c) Stainless steel lock-washers have been specified in place of cadmium plated lock-washers.

3.1.2.7 Leakage (Immersion) Test

The leakage test was conducted in accordance with Method 512, Procedure I of MIL-STD-810B. This test was performed prior to and following shock and vibration testing of the physically identical test item. These shock and vibration tests are detailed in paragraphs 3.1.2.8 and 3.1.2.9 below. Only the transit case and the HHLR were subjected to this test. The test item was immersed in water to a depth of 36 inches for 120 minutes. A visual inspection for any evidence of leakage and an operational test was performed at the conclusion of the test. The transit case passed the leakage test with no discrepancies. The Optical Assembly of the HHLR exhibited a leak in the eyepiece when immersed in water. The failure was traced to a sealing screw in the eyepiece diopter scale ring. The screw - a number 4-40 with an o-ring under its pan head - was threaded into the polycarbonate scale ring and served as a mechanical stop for adjustment provided by the eyepiece. Repeated contact of the screw against the stop deformed the threads of the polycarbonate scale ring and broke the seal. Replacement of the plastic scale ring with a metal equivalent from the Leitz Elcan 7 x 50 binoculars cured the problem and the test was passed successfully. The drawings were changed accordingly.

3.1.2.8 Shock Test

The shock test was conducted in accordance with Method 516.1, Procedure II and V of MIL-STD-810B.

Procedure II (transit drop test). The unit in its transit case was dropped from a height of 48 inches onto a 2 inch thick wood floor. The unit was dropped on each face, edge and corner for a total of 26 drops.

Procedure V (bench handling test). This test was conducted only on the HHLR. The unit was placed on each face on which it could be placed practicably during servicing. Each edge was raised 4 inches and the unit was allowed to drop freely to the bench top.

An operational test was performed at the conclusion of each test.

These tests were passed with no discrepancies.

3.1.2.9 Vibration Test

The vibration test consisted on two parts as follows:

PART I (Use environment). The equipment in its transit case was subjected to Method 514.1, Procedure XI Part 2 of MIL-STD-810. The test item was vibrated on a package tester, operated at 1 inch DA and 284 rpm for a total of 3 hours. At the end of each 1/2 hour period, the test item was turned to rest on a different face. An operational test was performed at the conclusion of this test.

PART II (transportation). This test was conducted in accordance with EL-CP5100-0001A Para. 4.4.9.1. The test item was instrumented with miniature accelerometers. The unit was then rigidly attached to a test fixture. The test item was vibrated along each of its three mutually perpendicular axes in accordance with the following:

(1)	Test level:	1 g
(2)	Frequency range:	4.5 to 500 Hz
(3)	Time schedule:	2 1/2 hrs per axis
(4)	Sweep rate:	4.5 - 500 - 4.5 Hz in 15 minutes

An operational test was performed at the conclusion of this test. These tests were passed with no discrepancies.

3.1.2.10 Leakage (Immersion Test)

The test discussed in paragraph 3.1.2.7 was repeated and passed with no discrepancies.

3.1.2.11 Fungus Test

The fungus test was conducted in accordance with Method 508, Procedure I of MIL-STD-810B. The test item was opened during test exposure and all internal surfaces were sprayed with spore suspension, as were the external surfaces. The test was continued for a period of 28 days. A visual inspection of performed at the conclusion of this test.

This test was passed with no discrepancies.

3.1.3 Nuclear

The HHLR successfully passed all of the requirements of the classified specification. Minor charring or discoloration of knobs and strap did not impair performance.

3.1.4 EMI

The AN/GVS-5( ), operating in its internal battery configuration, fully complied with RE02, RE02.1 and RS03.1 requirements of MIL-STD-461A, Notice 4.

The AN/GVS-5( ), operating in its external power configuration, complied with CE01, CE04, RE02.1, CS01, CS02, CS06 and RS03.1 requirements of MIL-STD-461A, Note 4. It exceeded the RE02 limits over the 23 kHz - 148 kHz frequency range by no more than 31 dB. A specification change has been requested.

Post qualification investigation results indicated that the EMI gasket for the telescope assembly can be eliminated from the design. This change will be made in future units.

3.1.5 Reliability

The AN/GVS-5(V) has a specified Mean Rangings Between Failures of 30,000. The predicted MRBF is 44,300 rangings, as shown in CDRL Sequence Number G004. The requirement has been verified by test, with the successful accumulation of greater than 54,000 rangings of two units without failure, as reported in CDRL Sequence Number G003.

3.1.6 Maintainability

The maintainability requirements of the AN/GVS-5(V) are:

(1) Mean Time to Repair

(a)	Organization	15 minutes
(b)	Direct Support	30 minutes
(c)	General Support	1 hour

(2) Maximum Time to Repair

(a)	Organization	30 minutes
(b)	Direct Support	1 hour
(c)	General Support	3 hours

Analysis indicated that direct support actions were not cost effective, so no maintenance actions were allocated to D. S. Maintainability detailed predictions (CDRL Sequence Number G009) showed that the Organization and General Support requirements could be achieved. A detailed maintainability demonstration verified that the requirements indeed had been achieved, given a modification in the General Support testing and purging protocols. Reference CDRL Sequence Number G007.

3.2 SPECIAL TEST EQUIPMENT TESTS

3.2.1 Bench Tests

During the design and assembly phase several bench tests were used to insure that the Test Set would function as specified and meet its technical specifications. One of the tests run was a temperature test of the power supply to insure that the power supply voltage would remain within the specified tolerance of ± 4 volts for the +100 volt supply and ± 0.3 volt for the +5 volt supply. All power supply outputs met their specification through several cycles of the operating temperature extremes of 0 to 60°C.

Temperature tests were also run on the oscillator, range timer, and target separation one shot. The oscillator frequency variations averaged about 5 Hz over the temperature range 0 to 60°C, which is within the ± 10 Hz tolerance.

The range timers measured less than 200 meters except that during an environmental run one unit went slightly outside the specified limits. An ECN at this time changed the timing capacitor to a more stable type (from a CK05 to DM07). This reduced the range variations due to temperature below the ± 50 meters due to pulse to pulse power and rise time variations. The change in the 200 meter target spacing was 20 meters over the operating temperature range.

The calibration was also checked during temperature testing on the bench and found to be within specifications over the operating temperature range. The repeatability and criticality of alignment of the calibration and test fixtures was checked during the design phase by repeated assembly, disassembly, and recalibration of the test sets to prove that the methods used were repeatable. To insure that the calibration was in fact adequate, extinction tests were performed on an outdoor test range which proved that a properly boresighted LR had the design sensitivity. In addition, to insure that the Test Set did not put out an excessive power, 6 dB attenuation was inserted between the LR and the Test Set receiver and the 1 TGT test run. Under these conditions, the Normal green light failed to come on.

3.2.2 Environmental Tests

GVST serial number 002 was subjected to the following environmental tests:

(1) Temperature testing at +131°F (55°C) and 32°F (0°C)

(2) Altitude testing at 10,000 feet and 50,000 feet

(3) Vibration and Shock testing

These tests were conducted in accordance with AN/GVS-5 Engineer Design Test Plan Di-T-1901 SEQUENCE NO J010 and Acceptance Test Plan Di-R-1701 NO G011. These test procedures were as follows:

3.2.2.1 Altitude Test

The altitude test was conducted in accordance with Method 500, Procedure I, of MIL-STD-810B. The equipment was subjected to a simulated altitude of 50,000 feet above sea level for one hour in a storage, non-operating mode. The chamber pressure was then increased to simulate an altitude of 10,000 feet and an operational test performed. During the functional tests performed at 10,000 feet altitude simulation, a man was in the chamber to perform the test and record the data.

3.2.2.2 Low Temperature Test

The low temperature test was conducted in accordance with Method 502, Procedure I, MIL-STD-810B. The unit was instrumented with thermocouples and then subjected to a storage temperature of -70°F for a period of 2 hours following stabilization. The chamber temperature was then increased to 32°F and an operational test performed. During the functional tests performed at 32°F, a man was in the chamber to perform the test and record the data.

3.2.2.3 High Temperature Test

The High Temperature Test was conducted in accordance with Method 501, Procedure II of MIL-STD-810B. The unit was instrumented with thermocouples and subjected to storage temperature cycling between 120°F and 160°F for 36 hours, after which the unit was stabilized at 131°F and a functional test was performed.

3.2.3.4 Vibration Tests

The CLIN 0002 unit in its transport mode was subjected to the vibration tests of MIL-T-21200L for Class 3 equipment. The equipment was subjected to continuous vibration along each of the three mutually perpendicular axes within the frequency range and amplitude as follows:

Frequency Range	Double Amplitude
5-15	0.06 inch
15-25	0.04 inch
25-55	0.02 inch

No resonance dwell was performed. Functional tests were performed before and after exposure to the vibration.

3.2.2.5 Shock Tests

The CLIN 0002 unit in its transport mode, was subjected to shock machine tests of half sine, 20 g peak, 11 msec pulse, in accordance with MIL-STD-810B, Method 516.1, Procedure I. These tests were passed with no discrepancies other than the single discrepancy discussed below.

One failure was noted during temperature testing in a 55°C ambient. This failure was caused by a high temperature coefficient capacitor on the electronics board (C4). This component was replaced with a type DM07 for better temperature stability and the test was then repeated and passed. A second GVST, serial number 003, was subjected to a humidity test per MIL-STD-810B, Method 507, Procedure II. The equipment was subjected to a 24 hour drying cycle followed by a 24 hour conditioning cycle and then five (5) continuous 48-hour cycles with humidity maintained at 94 percent and the temperature cycling between 70°F and 150°F.

A complete visual inspection was performed on the GVST following this test. Several problem areas were noted. These problem areas included degradation to the anti-reflection coating on the receiver/transmitter windows. This problem was also noted during humidity testing on the HHLR and corrective action was initiated at that time. The window coating degradation and corrective action are discussed in detail in paragraph 3.2.1.5.

The other problem was slight corrosion noted on the alignment bracket. Although not considered a failure in this test, drawing changes have been made to incorporate a finish change for future units. The change is from a hard anodize finish to a black anodize finish at the bottom of the bracket. The reason is the difficulty of obtaining a hard anodize on the inner perimeter, which has a sharp edge. In all other aspects, the humidity test was passed.

3.2.3 Summary

With the exception of the window coatings, discussed in paragraph 3.1.2.5, the environmental testing of the GVST has been successfully completed.

3.3 AZ-EL TESTS

3.3.1 Environmental Tests

As part of its Qualification Test requirement, the Az-El Head Set has been subjected to the environmental tests discussed in this paragraph. The Set has successfully passed all of these tests contingent on a retest, at the part level, of some items which failed the humidity and/or salt fog tests.

Table 3-2 lists the environmental tests which were performed on CLIN Model Serial Numbers 00002 and 00003. These units successfully passed Conformance Tests prior to the start of the environmental tests. The specific test methods and requirements and the resulting performance of the equipment are given in the sub-paragraphs below. Unless specifically stated otherwise in these subparagraphs, the Az-El Head Set, in toto, was subjected to all tests.

3.3.1.1 Altitude Test

The altitude test was conducted in accordance with Method 500, Procedure I, of MIL-STD-810B. The equipment was subjected to a simulated altitude of 40,000 feet above sea level for one hour in its transit case in a storage, non-operating mode. The chamber pressure was then increased to simulate an altitude of 10,000 feet and an operational test performed.

The Shelf Mount was excluded from this test which was passed with no discrepancies.

3.3.1.2 High Temperature Test

The High Temperature Test was conducted in accordance with Method 501, Procedure II of MIL-STD-810B. The unit was instrumented with thermocouples and subjected to storage temperature cycling between 120°F and 160°F for 36 hours. The chamber temperature was then maintained at 160°F and an operational test was performed.

The Shelf Mount was excluded from this test which was passed with no discrepancies.

3.3.1.3 Low Temperature Test

The low temperature test was conducted in accordance with Method 502, Procedure I, MIL-STD-801B. The unit was instrumented with thermocouples and

Table 3-2. Environmental Testing (Serial Nos. 00002 and 00003)

Specification EL-CP5112-0001A	Environmental Tests		
Design Requirement Paragraph	Model Serial Number	Test Identification	EL-CP5112-00001A Specification Test Para. Requ't.
3.3.2 through 3.3.8 as applicable	00002 00003	Conformance	4.7.4
3.2.3.1	00002	Altitude	4.4.1
3.2.3.2	00002	Temperature (High and Low)	4.4.2 & 4.4.3
3.2.3.5	00002	Sand & Dust	4.4.6
3.2.3.3	00002	Humidity	4.4.4
3.2.3.6	00002	Salt Fog	4.4.7
3.2.3.4	00003	Immersion	4.4.5
3.2.3.8	00003	Vibration	4.4.9.1
3.2.3.8	00003	Shock	4.4.9.2
3.2.3.4	00003	Immersion	4.4.5
3.2.3.7	00003	Fungus	4.4.8

and then subjected to a storage temperature of -70°F for a period of 2 hours following stabilization. The chamber temperature was then increased to -50°F and an operational test performed.

The Shelf Mount was excluded from this test which was passed with no discrepancies.

3.3.1.4 Humidity Test

The humidity test was conducted in accordance with Method 507, Procedure II of MIL-STD-810B. The equipment was subjected to a 24 hour drying cycle, a 24 hour conditioning cycle, and 5 continuous 48-hour cycles with humidity maintained at 94 percent and the temperature cycling between 70°F and 150°F. The unit was operated during each of the 48 hour cycles.

Both the Tripod and the Shelf Mount were excluded from this test.

The humidity test was failed because the GFE cam lock mechanism, which locks the AZ-EL Head to the tripod, froze and was not operable.

Other areas of minor corrosion were noted but did not affect operation and were not considered to be cause for failure of the test. These occurred on some black oxided parts, the azimuth ring, and the carrying case.

3.3.1.5 Salt Fog Test

The salt fog test was conducted in accordance with Method 509, Procedure I, of MIL-STD-801B. The test item was placed in a salt fog chamber and exposed to a 5 percent salt solution salt fog at a temperature of 95°F for 48 hours. A visual inspection was performed at the conclusion of the salt fog test.

The failure requirements for salt fog are defined in specification EL-CP5112-0001A paragraph 4.4.7 as follows: ".....corrosion of finishes and metals only. Such corrosion shall be defined as any visible degradation of the equipment surface that can be attributed to flaky, pitted, blistered, or otherwise loosened finish or metal surface." By this definition there were several failures during the test.

It should be noted that this test was run on the same unit that had been subjected to the humidity test. These failures and the subsequent corrective action are detailed in Table 3-3.

Table 3-3. Salt Fog Test Failures

Item	Problem	Corrective Action
1.	Cam lock mounting mechanism exhibits rusting and is difficult to operate. This item is GFE.	Change material of locking mechansim from 400 series to 300 series CRES or for heat treated parts to 17-4 type CRES. Change aluminum coating to MIL-A-8625, Type II.
2.	O. D. paint on azimuth support blistered.	Change paint to PXYZ-M per MIL-F-14072 with MIL-P-23377 primer.
3.	Battery compartment cover exhibits blistering of Ni plate.	Assure that all external edges, not protected by paint, are radiused.
4.	Moisture on inside of 1 mil indicator window.	A leak in the window seal was found. This was a workmanship problem.
5.	Night vision guide blocks exhibit rust and white corrosion at interface.	These are made from 300 series CRES with a black oxide coating and should not rust. This is believed to be a processing problem.
6.	HHLR mounting bracket exhibits white corrosion products at capscrew holes.	This was not made per drawing but per an ECN which allowed a "touchup" in the holes after machining. These holes must be anodized per MIL-A-8625.
7.	Elevation knob eccentric housing ss/alum. interface corrosion.	Aluminum surfaces must be anodized per MIL-A-8625.
8.	Azimuth adjusting mechanism frozen. corrosion on azimuth driven spindle assembly and cavity (this is GFE).	The aluminum cavity must be anodized per MIL-A-8625.
9.	Output shaft eccentric ss/alum	Anodize aluminum surface per MIL-A-8625.
10.	MT4881 mounting bracket captive screws rusty.	These are made from 300 series CRES with a black oxide coating and should not rust. This is believed to be a processing problem.
11.	Base tripod mount threads rusty.	See #10
12.	Carry case latches rusty.	Replace with 300 series CRES latch.
13.	Transit case piano hinge has very slight discoloration.	Very minor, no action necessary.

Drawing changes per this corrective active have been made, but no retest is planned.

3.3.1.6 Sand and Dust Test

The sand and dust test was conducted in accordance with Method 510, Procedure I of MIL-STD-801B. The unit was subjected to air velocity of 1750 feet per minute with a dust concentration of 0.3 gms per cubic feet for six hours while at a temperature of 73^{o}F. With the dust feed stopped, the temperature was increased to 145^{o}F and the humidity held at less than 10 percent for 16 hours. The temperature was maintained at 145^{o}F and the dust feed started and maintained as before for six hours. A visual inspection for mechanical degradation and an operational test were performed at the conclusion of the test. This test was passed with no discrepancies.

3.3.1.7 Leakage (Immersion) Test

The leakage test was conducted in accordance with Method 512, Procedure I of MIL-STD-810B. This test was performed prior to and following shock and vibration testing of the physically identical test item. These shock and vibration tests are detailed in paragraphs 3.3.2.8 and 3.3.2.9 below. Only the transit case and the Az-El Head were subjected to this test. The test item was immersed in water to a depth of 36 inches for 120 minutes. A visual inspection for any evidence of leakage and an operational test was performed at the conclusion of the test. The transit case passed the leakage test with no discrepancies.

Initial Leakage Tests showed a few drops of water in the elevation housing and an ounce or so of water in the battery compartment. The leakage in the elevation housing was traced to installation of an incorrect O-ring on the plunger shaft. The leakage in the battery compartment was found to occur along a potted-wire joint. The procedure and sealing material was changed to eliminate this leak path and the test was passed.

3.3.1.8 Shock Test

The shock test was conducted in accordance with Method 516.1 and Procedure II and V of MIL-STD-810B.

Procedure II (transit drop test). The unit in its transit case was dropped from a height of 24 inches onto a 2 inch thick wood floor. The unit was dropped on each corner for a total of 8 drops. The Shelf Mount was included in these tests.

Procedure V (bench handling test): This test was conducted only on the Az-El Head. The unit was placed on each face on which it could be placed practicably during servicing. Each edge was raised 4 inches and the unit was allowed to drop freely to the bench top.

An operational test was performed at the conclusion of each test. These tests were passed with no discrepancies.

3.3.1.9 Vibration Test

The vibration test consisted of two parts as follows:

PART I (Use environment). The equipment in its transit case was subjected to Method 514.1, Procedure XI Part 2 of MIL-STD-810. The test item was vibrated on a package tester, operated at 1 inch DA and 284 rpm for a total of 3 hours. At the end of each 1/2 hour period, the test item was turned to rest on a different face. An operational test was performed at the conclusion of this test.

PART II (transportation). This test was conducted in accordance with EL-CP5112-0001A Para. 4.4.9.1.b. The test item was instrumented with miniature accelerometers. The unit was then rigidly attached to a test fixture. The test item was vibrated along each of its three mutally perpendicular axes in accordance with the following:

Test level:	1.5g
Frequency range:	5.5 to 200 Hz
Time schedule:	84 minutes per axis
Sweep rate:	5 - 200 - 5 Hz in 12 minutes

An operational test was performed at the conclusion of this test.

These tests were passed with no discrepancies.

3.3.1.10 Repeated Leakage (Immersion) Test

The AZ-EL Head, adapter, and hard carrying case passed this test with no discrepancies. Minor signs of fungus growth were seen on the foamed insert in the transit case and in one area around the zipper of the soft carrying case. These are attributed to contamination due to handling and lack of cleaning prior to the test. No retest is planned for these cases.

The wooden instrument box showed signs of fungus growth. However, since it is not planned to use this box for production units, no redesign or retest is planned.

3.3.1.11 <u>Fungus Test</u>

The fungus test was conducted in accordance with Method 508, Procecure I of MIL-STD-810B. The test item was opened during test exposure and all internal surfaces were sprayed with spore suspension, as were the external surfaces. The test was continued for a period of 28 days. A visual inspection was performed at the conclusion of this test.

SECTION 4

CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

The AN/GVS-5( ) Engineering Development Models designed and produced under contract DAAB-07-74-C-0270 fulfilled all of the technical objectives of the contract.

- Ranging performance and characteristics met or exceeded specifications.
- Optical characteristics met or exceeded specifications.
- Battery life between recharges exceeded specification.
- Weight was approximately 0.3 lb. less than the 5 lb. limit.
- The equipment generally withstood the required environmental exposures, both operating and non-operating.
- The MRBF (reliability) met the specification requirements.
- Human engineering, safety and maintainability requirements were met.

In addition to fulfilling the technical requirements, the equipment design was achieved within the constraints of the design to cost goal.

4.2 RECOMMENDATIONS

The recommendations which follow are based upon RCA and Army experience in test, field usage and handling of the equipment. Their purpose is to enhance performance, reliability and survivability in the military environment, maintainability and producibility.

4.2.1 Lasor Rangefinder MX-9838( )/GVS-5

4.2.1.1 Optical Assembly

The following changes are recommended for the optical assembly:

(1) Add stiffening ribs to the main body casting to improve machineability and costs.

(2) Change the Sighting/Receiving objective lens seal from a gasket seal to an O-ring seal to reduce leakage and to minimize the lens positional shift potential.

(3) Change the Sighting eyepiece barrel seal from a gasket seal to an O-ring seal to reduce leakage potential.

(4) Change the Transmitter Telescope eye lens holder to a screw ring retainer to reduce risk of fractures.

(5) Change narrow bandpass filter holder to facilitate replacement and to allow back lighting of the receiver field stop.

(6) Change configuration of start pulse diode window to improve pick-up of scattered light.

(7) Enlarge the reticle apertures to improve registration of the projected Multiple Target and Battery Low LED images.

(8) Improve the uniformity of reticle illumination.

(9) Consider using "Beta Lite" reticle illuminators.

4.2.1.2 Laser Transmitter Module

(1) Modify module to use connectors on the flashlamp electrodes and trigger wire to reduce lamp cost, facilitate manufacture and simplify module replacement.

(2) Change housing to provide increased clearance between the resonator and the housing.

4.2.1.3 Range Counter/Display Board

(1) Reduce tolerances on Multiple Target and Battery Low LED locating dimensions and mount them to illuminate the projection lens for improved registration and brightness.

4.2.1.4 Video Amplifier and Range Counter

The lead frame connection pins on the two microcircuits should be replaced with swaged pins to facility assembly and repair. Lead frame pins are fragile and susceptible to failure if reworked or mechanically stressed. Protective resistors located at the connector pins or in the flexible printed wiring should be incorporated into the hybrid microcircuit as thick film resistors on the substrate.

4.2.1.5 Video Amplifier Circuit

The video amplifier circuit should be modified to slow the time programmed gain recovery time to minimize false alarms under snow and fog conditions.

A further modification to improve multiple target resolution from the present 70 to 80 meters to 25 to 40 meters can be accomplished and is recommended as the basis of proposed use of AN/GVS-5 modules with last-target range logic for vehicle application.

4.2.1.6 Trigger Circuit and PFN Capacitor Mounting

Although the AN/GVS-5 withstood all of the specified vibration, shock, bench handling and bounce tests required by specification, several units were dropped and experienced very severe shock. As a result the PFN capacitor and in one instance the trigger circuit mountings fractured or separated. Strengthening of the mounting structure for these parts is recommended to enhance the survivability of the units in the field.

4.2.2 Laser Rangefinder Case CY-7536( )/GVS-5 and Case CY-7537( )/GVS-5

A desirable change to the carrying case would be the elimination of the ridge at the cover-case junction to make it more comfortable to carry.

The transit case is adequate for its intended function. No change is recommended.

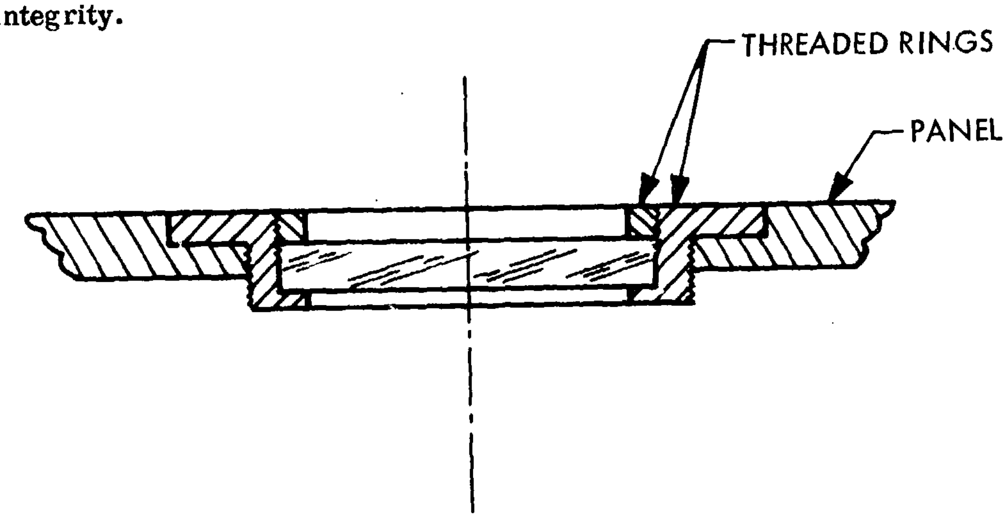
4.2.3 Special Purpose Electrical Cable Assembly CX-13021( )/GVS-5

RCA believes that the remote power cable should protect the AN/GVS-5 from voltages above 30V and from polarity reversal. It should not be required to operate the AN/GVS-5 during the abnormal conditions of paragraph 5.4 of MIL-STD-1275 which are stated in MIL-STD-1275 as violating paragraph 5.1 of the spec. The present design provides operation under the 30 - 40 volt condition and as a result dissipates considerable power and is very costly.

A design change to simplify the remote power cable is recommended.

4.2.4 Laser Rangefinder Test Set TS-3620( )/GVS-5

The only recommended change to the GVST is to change the method of mounting the optical windows to the control panel. The current design specifies that these windows are bonded to the panel. A recommended change would be to attach the windows with threaded rings, as shown below, so as to provide mechanical retention in addition to the bond and thus greater structural integrity.



APPENDIX A

PERTINENT EXCERPTS FROM THE
DESIGN PLAN

SECTION 2

BASIC DESIGN APPROACH

2.1 PACKAGING DESIGN

2.1.1 HHLR Housing

The HHLR is contained within a two piece housing consisting of the Control Panel and Cover Assemblies. Together they form a protective enclosure for the electronic circuitry and the laser optics. Additionally, they have been human engineered to provide ease of handling and operation.

The Control Panel, shown in Figure 2-1, is the prime structure of the equipment. It supports all of the parts, components, and subassemblies that form an operable device. From a structural viewpoint, the Control Panel is designed to provide adequate load paths to prevent permanent deformation under conditions of handling shock. Supporting analysis is summarized in Paragraph 3.2.

As its designation implies, the Control Panel mounts all the controls and other functional elements necessary for operation. Placement is dictated primarily by human engineering requirements and secondarily by packaging convenience. The placement also provides some degree of improvement in structural rigidity without the addition of excess weight. This is achieved by increasing the inertia properties with ribs and hat sections.

The Control Panel is of investment cast construction. This process allows minimum wall thicknesses consistent with the need to minimize weight. Some sections may be as little as 0.04-inch thick with highly stressed areas around the telescope mount, the adapter mount, andthe sealing flange of heavier sections to provide proper load paths. The aluminum alloy will be Type 356 or A356 combining good castability, mechanical properties, corrosion resistance, and machinability in thin-walled castings. An alternate process would be die casting at the penalty of some increase in weight but reduced cost. Type 380 or A380 alloy would then be used to attain the same desirable characteristics. The cost/weight tradeoff is described in Section 3.3.

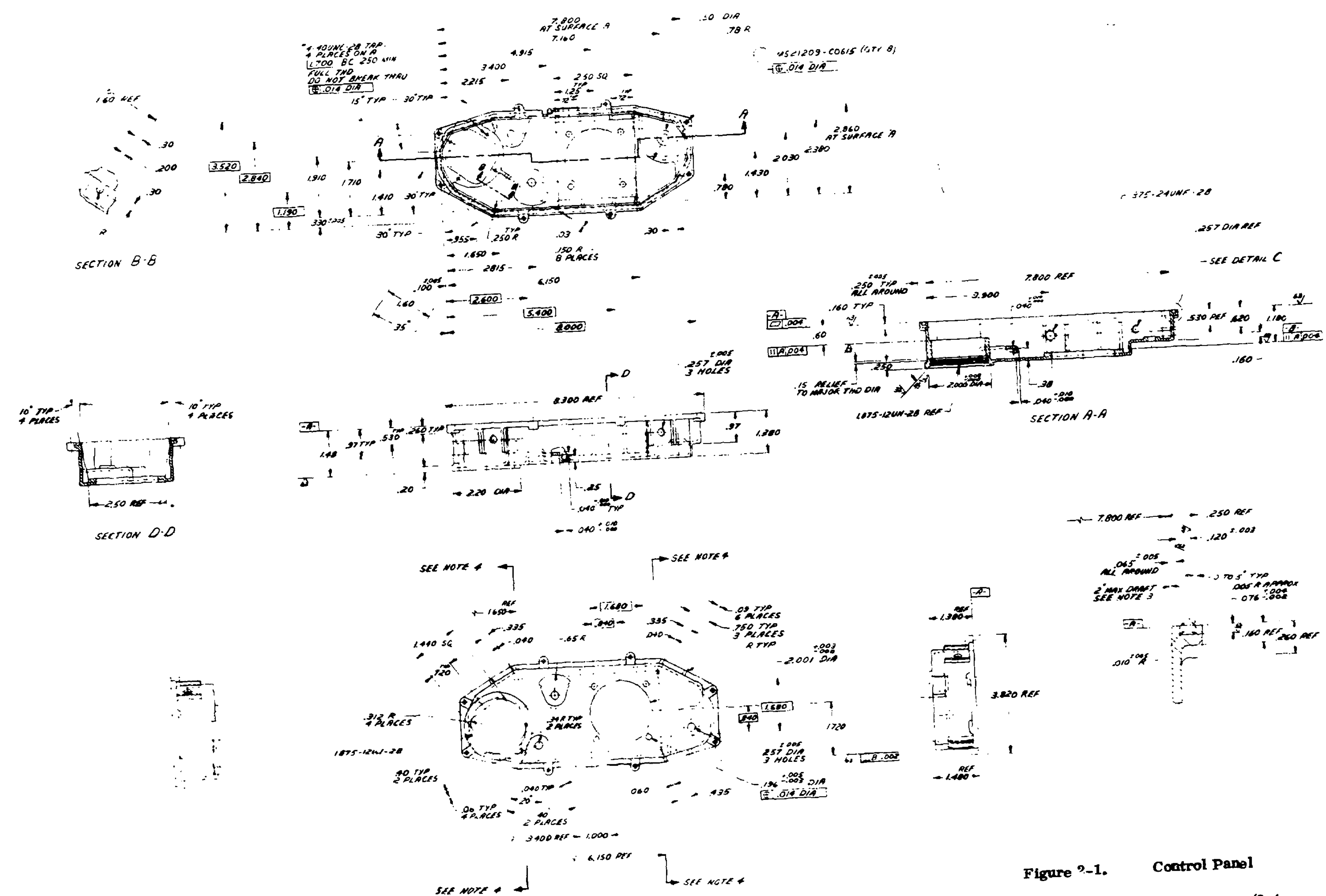


Figure 2-1. Control Panel

At the interface with the Cover Assembly, a 0.275 inch wide by 0.160 inch thick flange is provided. This flange, with its good load path into the walls, provides both structural stiffness for shock loading and minimum deflection and low stress under pressure loading. This flange also has a groove to take a formed "O" ring type gasket needed for a pressure seal. Eight bosses, containing helical-coil inserts, are approximately equally spaced for optimum pressure and EMI sealing with the Cover Assembly.

Attached to the lower part of the control panel is an adapter containing a male V-groove. This adapter is accurately aligned to the telescope mount to provide the interface through an adapter mount to various night vision devices and an Azimuth-Elevation Head (AEH). To reduce wear and the possibility of accuracy-affecting damage, the adapter is fabricated of corrosion resisting steel finished with an oxide coating to prevent specular reflections. The adapter is attached to the casting by a threaded bushing and pins to maintain alignment. The bushing is threaded into the casting with an adhesive which will bond it to the casting as well as seal it to prevent leakage. The bushing contains a blind 1/4-20 tapped hole for retention of the HHLR to its various adapters, the AEH and any standard tripod, either military or commercial.

Corrosion resisting steel pins driven into bosses at each end of the casting are provided for neck and hand retention straps.

The battery compartment access is an integral part of the control panel assembly. It contains a cast-in feature to guide the square battery properly into its compartment. A coarse thread and a surface for pressure sealing are provided for the screw-in battery cover. Other features and requirements of the battery compartment/cover are detailed in Section 2.1.3.

The control panel assembly, shown in Figure 2-2, has been configured for ease of operator use. Controls lie near the normal operating fingers as they hold the assembly in operating position. To provide a capability of operation with arctic mittens as well as bare hands, some compromise had to be made in control placement. However, a trained operator, gripping the assembly with his elbows close together and tight against his chest for steadying, can reach all controls except the power switch with either his thumbs or forefingers. Other details of the controls are covered in Section 2.9.

The Control Panel is finished with a conductive chemical conversion coating for corrosion protection and as a primer or undercoat. The exterior is finished in lusterless black with a textured polyurethane finish. At temperatures below freezing, it provides a surface that prevents skin from sticking as on bare metal.

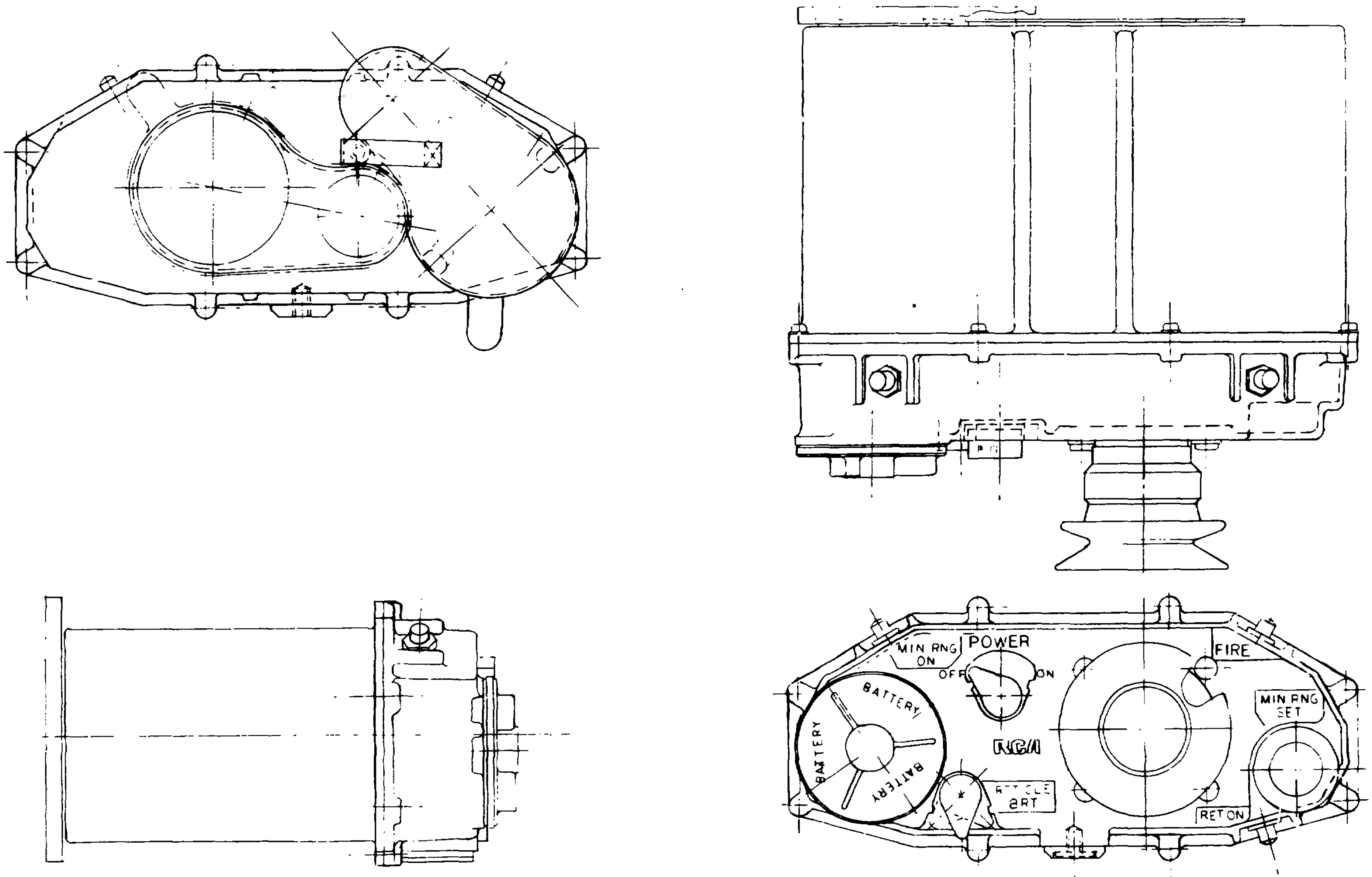


Figure 2-2. Control Panel Assembly (Sheet 1 of 2).

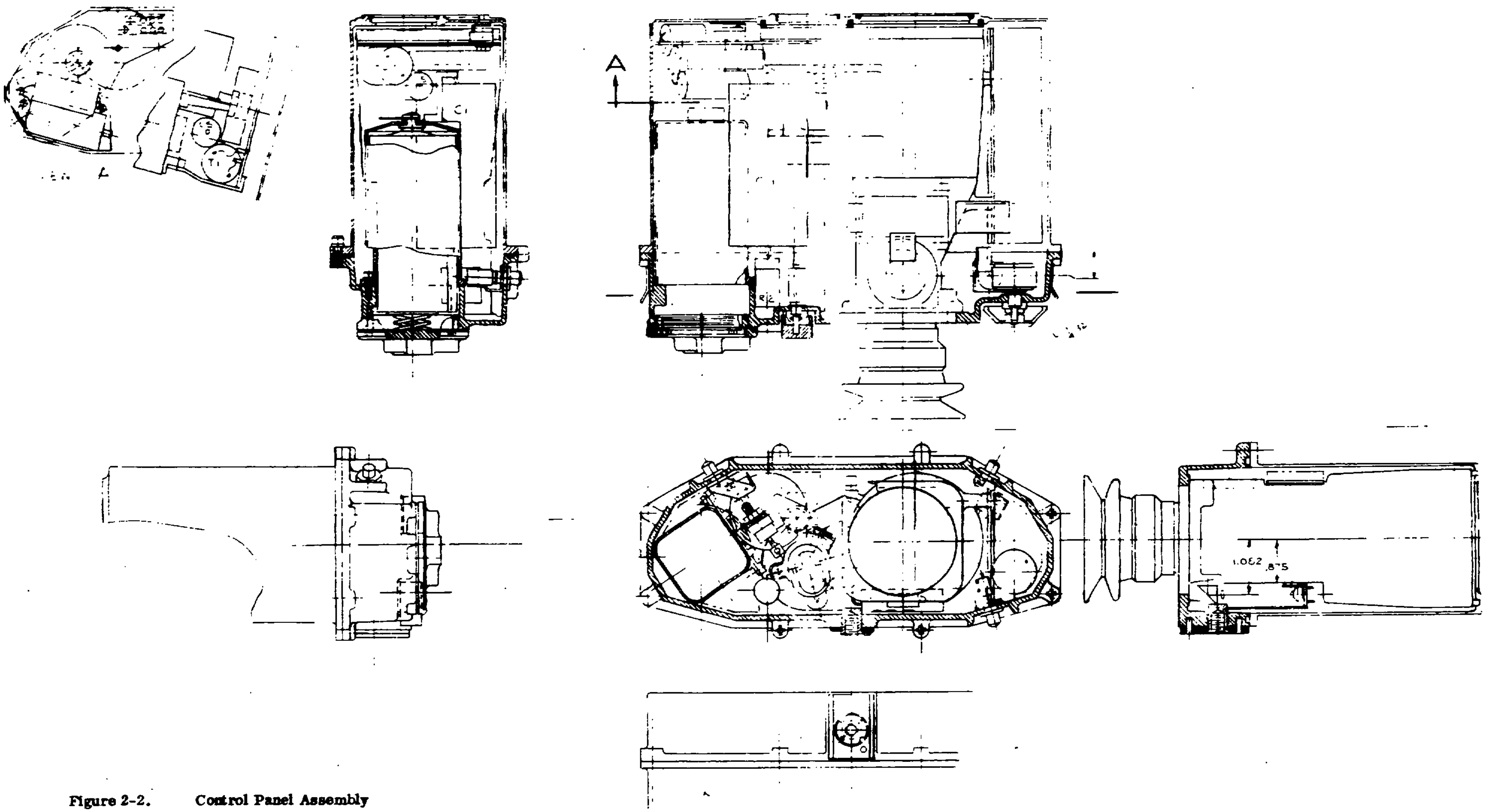


Figure 2-2. Control Panel Assembly (Sheet 2 of 2).

An etched metal plate containing the control nomenclature and other data is bonded to the front surface of the Control Panel with an adhesive that will withstand all the environments. The nam ate will be bonded to the top surface of the assembly between the two bosses.

The Cover Assembly, shown in Figure 2-3, makes up the other part of the housing. Besides its functional use as an enclosure it supports the optical windows, and a strap retention pin. Additionally, it has been human engineered to form a comfortable hand grip with finger holds.

Being primarily an enclosure, the cover need only be of sufficient rigidity to withstand the highest pressure differential and maximum handling and shock loads to reduce weight to a minimum. Except for the mounting/sealing flange and the window retention features, the basic metal thickness in aluminum is 0.035 inch nominal. To provide the required rigidity and the finger holds, hat sections will be formed in the skin. These add very little weight while greatly increasing structural stiffness.

The flange provides one half of the sealing interface and is of sufficient thickness, 0.150 inch, to withstand the combined stresses induced by differential air pressure and gasket compression while maintaining an air and EMI tight seal. The structural analysis is detailed in Section 3.2 substantiated in part by tests detailed in Appendix 9.7.

Raised sections around the windows form retention and bonding surfaces for the glass to metal seal. This seal will be made by a bonding operation using an elastomer (EC801) which has the required high peel and shear strengths. The transmitting telescope window is bonded at a slight angle to prevent reflection back into the laser cavity. Flanges around the windows captivate pressed on covers. Cost, weight, and reliability tradeoffs are heing made of alternate window retention methods.

The strap retention pin is pressed into bosses on the cover for the single hand retention strap.

Attached to the front of the Optical Assembly is a ight-tight EMI type elastomeric seal. This seal serves three functions. First, when in contact with the cover, a seal is made to effectively attenuate internally and externally generated EMI. Second, it provides a light seal to prevent the exiting laser light from entering the receiving portion of the telescope. Third, it provides snubbing action with the cover to attenuate handling shock loads.

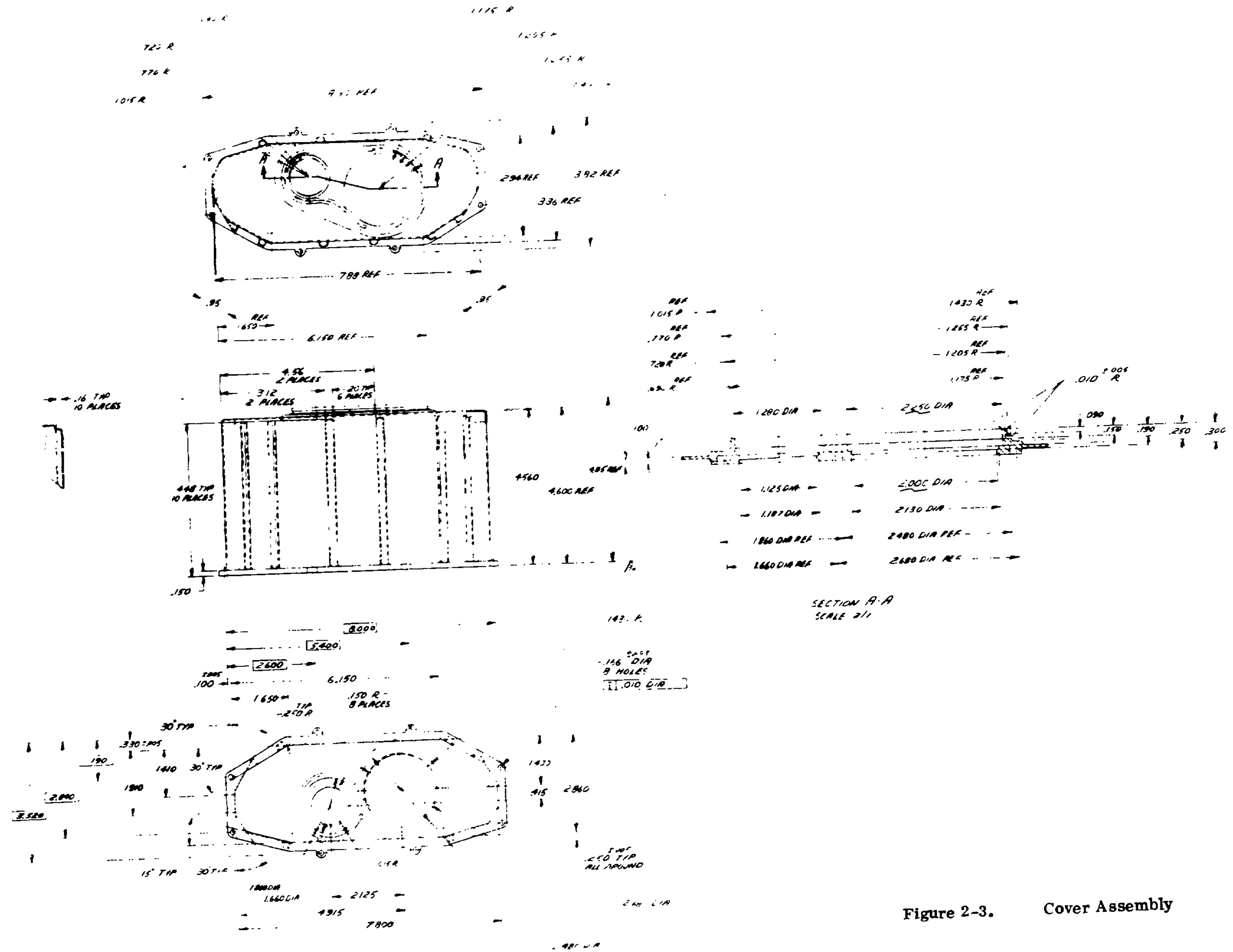


Figure 2-3. Cover Assembly

The cover assembly will be finished in texturized polyurethane olive drab paint. Radiation warning labels will be visible to the operator.

2.1.2 Electronic Packaging

The HHLR electronic packaging is such that removal of the cover leaves a completely operable assembly. This is advantageous from both the manufacturing and maintenance aspects for any equipment. There are two micro-switches acting as safety interlocks that require overriding for operation. It is felt that only personnel skilled in this particular device should be allowed to operate or maintain the equipment with the cover-off.

To allow this open operation all the parts and assemblies are mounted to the Control Panel Assembly. The assemblies that may be necessary to be removed for servicing are made easily removable.

The battery compartment, although not a functional assembly, is considered as a part of the electronics. Since the battery has to be readily replaceable in adverse field environments, the compartment is sealed off from the inside of the assembly. This is accomplished by bonding the inside portion to the Control Panel Assembly. Additionally, four screws will be used to hold this portion to the Control Panel Assembly. This part will contain the positive battery contact.

The battery cover, an aluminum casting, is the negative battery contact. To assure a reliable contact, the cover will have plated threads and surfaces to which will be attached the spring contact. This spring will be of beryllium copper or phosphor bronze for good electrical conductivity with proper spring characteristics. A minimum loading of three pounds will assure proper contact under all but the most severe shock loads, which will not occur under operating conditions. The cover will be retained by a cable to the Control Panel Assembly to prevent inadvertent loss.

An 'O' Ring seal will prevent contamination and water entry when the cover is tightened. A minimum of 1 1/4, 12-pitch, threads is required for proper sealing. Finer threads require more turns; coarser, less, but with the penalty of greater pitch diameter (increased size and weight) to clear the battery. Accounting for manufacturing tolerances, the actual turns required will be 1 1/2 to 2 turns.

Since the battery cover is a casting, it is convenient and cost effective to cast in the following wording:

USE BB-516 BATTERY
INSERT (+) END FIRST
REMOVE FOR SHIP/STORE

The battery well, of injection molded polycarbonate, forms a structure to mount the pulse-forming network and the trigger circuit. The latter is a printed circuit assembly containing, in addition, the two interlock switches and the pulse forming inductor. This assembly, described elsewhere, is mounted by means of brackets and hardware to the rear of the battery compartment. The pulse forming network capacitor is attached by brackets and hardware to the side of the battery compartment. The diode associated with with the pulse forming network is stud mounted to a cast-in web on the Control Panel. The grounded side of this diode is case ground.

Except for the flash lamp and trigger wire in the laser transmitter which lies immediately adjacent, these components and assemblies form the complete triggering and pulse forming parts of the circuits. Since they are so closely associated, interwiring can be as short as possible.

Due to the number of separate parts and assemblies as well as the relatively high voltages, most interconnections to the PFN/trigger loop will be hard wired. The soldered connections of voltages greater than 70 volts above ground will be protected with a conformal coating of a formulation and thickness to provid operator safety with the cover off.

The telescope and its attached parts and assemblies form the major internal subassembly. Since there are requirements for close tolerance alignments of the optical lines of sight to the adapter mount, the telescope and its mounting interfaces form a rigid, stable structure. This provides additional mounting area for the lighter subassemblies and parts.

Two sensors, the start photodiode and the detector/preamplifier, are directly functional in combination with the telescope and are located and mounted to the telescope as functionally required. The counter/display module, with the LED digit and lamp readouts, is also directly functional and so mounted. The remaining electronic modules, the video amplifier and the power supply are indirectly functional and are mounted on the telescope for convenience and proximity to the circuits with which they are associated. The video amplifier and the counter/display are hybrid circuits that are on alumina substrates that require special mounting to prevent breakage. The power supply is of conventional printed circuit construction on glass-filled resin boards that are mounted by conventional hardware.

The other major item attached to the telescope is the laser transmitter assembly. This assembly requires accurate alignment that is in-built to the assembly and its mounting interface. Mounting is into a piloted hole and attachment is by conventional hardware. Electrical connections are hard wired to the pulse forming and trigger circuits that are in close proximity.

An incandescent lamp illuminates the reticle through a window in the side of the optical assembly. To reduce weight, this lamp will not be placed in a socket but will be a tight fit in an elastomer for retention.

Except for the hard wiring already mentioned, most other interconnections will be by flexible printed wiring. Wiring to the front panel mounted parts, two potentiometers and four switches, will be either flexible printed wiring, flat wiring, or individual wires tied into the flexible wiring. Accessibility for replacement is good except for these panel mounted parts. The switches are standard MIL parts with a good history of reliability. The two potentiometers are accessible for replacement without removal of other parts or assemblies other than the loosening of hardware.

2.1.3 Environmental Protection

Electro-optical equipment intended for outdoor use requires the optical elements and, usually, parts of the electronics to be placed in a sealed, dry atmosphere. The HHLR is no exception. The enclosure, therefore, is intended to provide such a sealed environment and yet the electronics and laser transmitter must be accessible for maintenance.

The previously mentioned gasket of "O" ring cross-section, shaped to fit the groove in the Control Panel Assembly, provides the housing seal. It will be of standard 0.103 inch diameter cross-section. Groove depth is adjusted to give 20 - 30% compression or approximately 0.02 inch minimum. To provide a reliable seal at the low temperatures expected the gasket will be fabricated from a silicone rubber compound. Durometer will be approximately 60 to reduce the linear pressure on the seal joint to the minimum and yet allow a good seal up to a 15 psi pressure differential. This also will meet the water immersion requirements of a three foot head.

The mounting surfaces, being electrically conductive, will effect a metal-to-metal seal. However, good electrical conductivity will occur only in the vicinity of the eight approximately equally spaced bolts. Between bolts there will be slight separation (less than 0.005 inch) of the mating surfaces due to pressure from the "O" ring gasket. In case a good EMI seal cannot be maintained, the gasket will be fabricated from a conductive elastomer. In this event special platings may be required on the mating metal surfaces to prevent corrosion due to dissimilar metals in contact, with moisture present.

Additional static seals are used at other interfaces with the Control Panel Assembly. The seal at the telescope eyepiece will be achieved with a shaped gasket of identical material, durometer, and cross-section to the housing seal. The cast-in groove will be in the telescope, mating to a flat machined surface inside the Control Panel Assembly.

The Battery Compartment will be sealed to the Control Panel Assembly by the use of an adhesive/sealant. The Battery Cover, although not required to provide a seal to the internal electro-optics, will be gasketed to provide a water tight enclosure to the battery compartment. This will be provided by a circular "O" ring of silicone rubber for highest elasticity at low temperatures.

The control seals are of two types. For the pushbuttons, a standard MS pushbutton seal, shown in Figure 2-4, will be used. Additional EMI gasketing is not required because of the metal to metal contact of the push pin and bushing. The rotary controls will use a similar MS rotary shaft seal, with or without a built in mesh type EMI seal, as applicable. As an added measure of protection, "O" ring gasketing will be used or the control shafts.

Rivets and other hardware that pass through the Control Panel and Cover Assemblies walls, will be coated with an adhesive/sealant. The seal around the optical windows is provided by the bonding material holding them to the Cover Assembly.

A purge port, normally covered with a sealing type screw, is on the Cover Assembly adjacent to the optical windows. Analysis shows that the dew point of the contained gasses must be extremely low to prevent condensation at the lowest expected temperatures. The unit is therefore purged and filled with dry nitrogen under normal atmospheric pressure.

The dynamics, vibration and shock requirements are met by the equipment both in and out of its carrying/transit case as applicable. The analyses, shown in Section 3.2, indicate that designing for a handling shock of 35 g will meet the dynamic environments of the equipment in its transit case.

Lens Covers - Molded lens covers will be provided. The operator may remove and store these in his pocket or the carrying case, as desired.

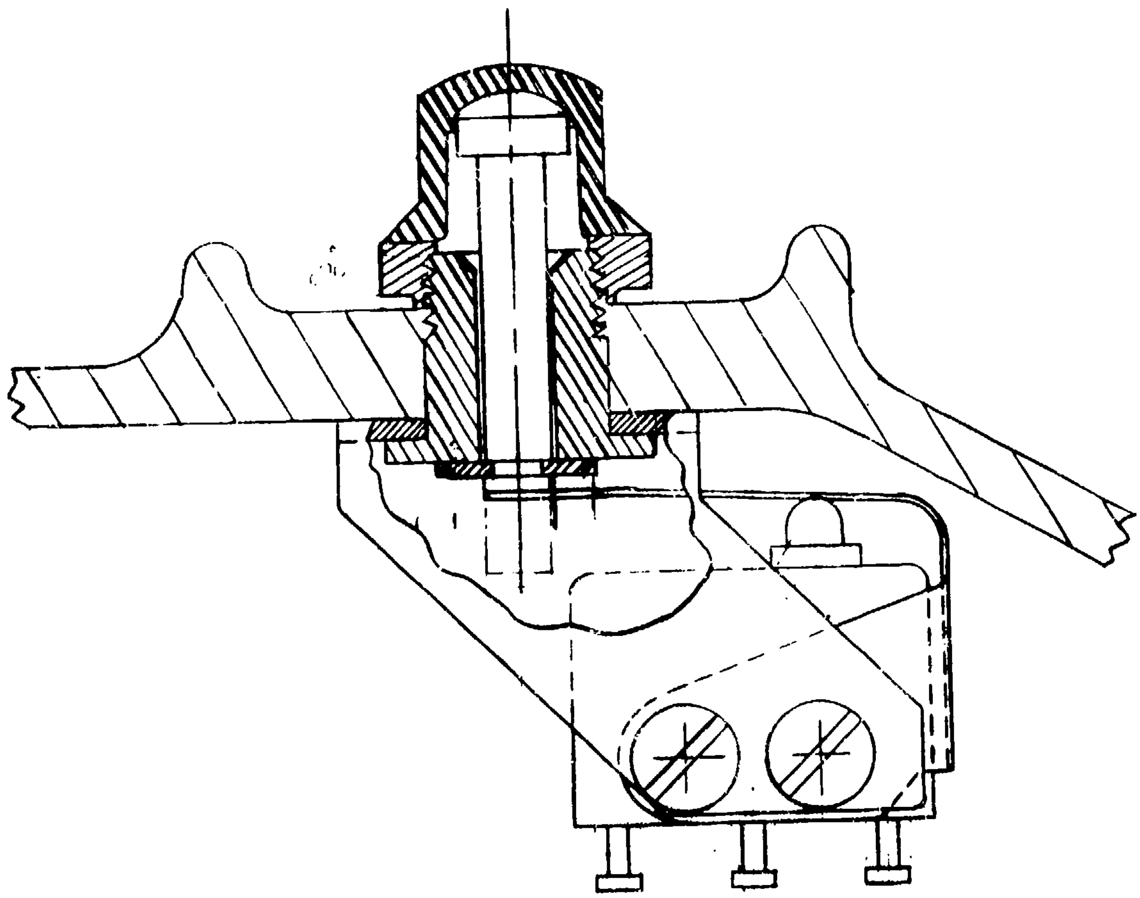


Figure 2-4. Standard Pushbutton Seal

2.2 OPTICAL ASSEMBLY

2.2.1 External Configuration

The Optical Assembly of the HHLR consists of two telescopes in one common aluminum casting: a transmitter telescope to steer the laser beam and reduce its angular beam divergence, and a coaxial sighting and receiving telescope to sight on the desired target and receive the reflected laser energy. The sighting/receiving telescope is an adaptation of the Leitz ELCAN 7 x 50 binocular developed for the Canadian military. There were several reasons for choosing this binocular. First, the magnification and field-of-view were identical to that required for the HHLR. Second, it was a modern militarized design undergoing qualification testing and field evaluation. And, third, the form factor of roof prism binoculars gives a more nearly cylindrical package in contrast to the more common porro prism design with offset objective and eyepiece lens axes. The roof prism form factor allows better utilization of available space and improves packaging density.

The Optical Assembly is a major structural support and mount for the laser transmitter module, the power supply module, the detector/preamplifier module, the video amplifier, and the range counter/display assembly. These subassemblies mount to cast bosses in the telescope housing. While the telescope will be black anodized to reduce reflections, subassembly mounting surfaces and the front and rear surface of the telescope housing will be finished in a low resistivity iridite to maintain electrical grounding and to reduce EMI radiation.

The transmitter and sighting/receiving telescope barrels, although part of the same casting, are optically isolated from one another by a structural wall to prevent strong laser light from getting to the sensitive detector. Each telescope is purged and sealed independently for this reason. The purging technique for the telescope is to draw a vacuum through a tapped hole in the housing and back fill with dry nitrogen. This may be repeated two or three times to lower the gas dew point to an acceptable level. The telescope is sealed with the internal nitrogen at ambient pressure.

The Envelope Drawing for the Optical Assembly is given in Appendix 9.1.

2.2.2 Sighting/Receiving Telescope

The sighting/receiving telescope, as mentioned above, is a coaxial system designed around the Leitz ELCAN 7 x 50 binocular. The basic change to these optics - which consist of an objective lens doublet, two erecting prisms, reticle and eyepiece - is the addition of a beam splitter cube between the erecting prisms and the reticle. The beam splitter cube is a coated prism surface that allows visible light to pass through but reflects laser light at 10,648Å at 90 degrees to the optical axis. The optical axis of the sighting system is determined by the reticle; the optical axis of the receiver is determined by the field stop. To establish these axes coaxial to one another and to ensure conjugate focus of the objective lens on the reticle and field stop, the erecting prisms, beam splitter cube, reticle, and field stop are a prealigned, bonded, optical assembly. Relative motion is thereby eliminated between the reticle and field stop so that the target the operator sees is the target imaged on the detector. The alignment tolerance on these two axes is 0.1 milliradian over the range of environmental conditions.

The objective lens is fixed focus with a usable operating range between 200 meters and infinity. This is to say that with the eyepiece focused on the reticle pattern the sighted scene will be in focus (within 1/8 diopter) from 200 meters to infinity from the operator. The eyepiece of the sighting system has ±4 diopters of focus adjustment to accommodate variation in operator visual anomolies. The eyepiece exit pupil is focused 17.5 mm behind the rearmost metal surface of the eyepiece. The sighted field-of-view of the telescope is 7 degrees. A system optical schematic is shown in Figure 2-5.

The operator is protected from returned laser energy through the sighting optics by a series of four dielectric filters cascaded in the path. The total attenuation of 10,648Å energy is in excess of 10^4 by the filters. By cascading the filters the danger of eye damage from pinholes in a filter is elimirated. The first filter is actually the dichroic beam splitter which reflects the laser light to the field stop. The transmission of this surface is expected to be less than 10 percent. The other three filters are coated onto lenses of the eyepiece.

The receiver telescope consists of the shared objective lens, erector prisms and beam splitter cube, the field stop, collimating lens, narrow bandpass filter, and a focusing lens to image the field stop on the detector. The field stop limits the field-of-view of the receiver to one milliradian. The magnification of the receiver telescope is approximately 67 power so that the diameter of the collimated light through the narrow bandpass filter is approximately 0.75 mm. The narrow bandpass filter allows only energy at the laser wavelength (10,648Å ± 50Å) to be transmitted to the receiver detector.

The practical design of the receiver is such that the prisms and field stop are mounted in a cell inside the telescope and the detector is mounted to the telescope housing exterior. The prisms and the housing have different thermal expansion rates so the optical design must accommodate some shift between the field stop and the detector. The relationships between the field stop and collimating lens, and between the focusing lens and the detector (see para. 2.5.1)

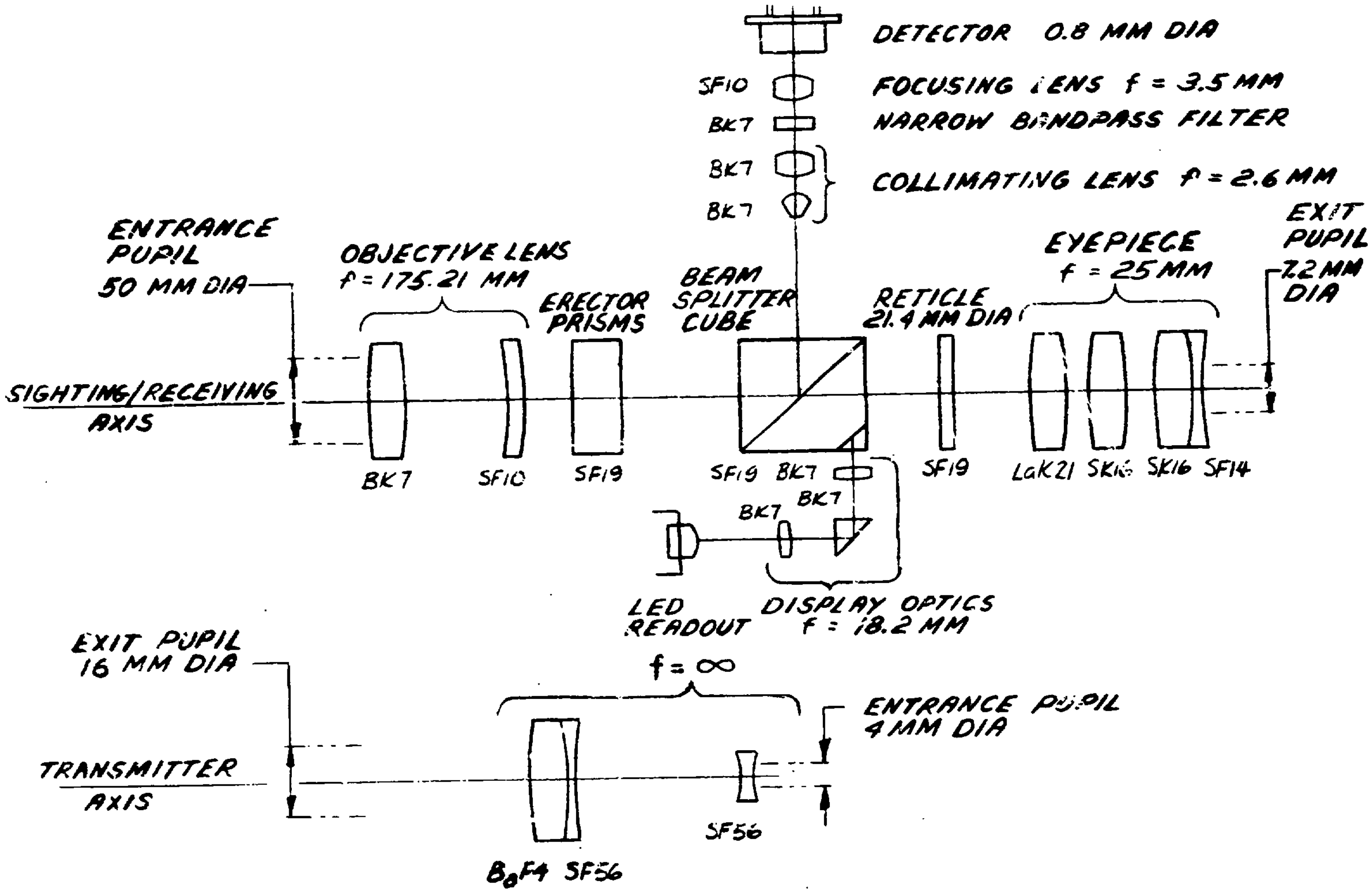


Figure 2-5. AN/GVS-5 ( ) System Optical Schematic

are critical so the shift must be absorbed in the collimated path between the collimating and focusing lenses. The actual shift (approximately 0.003-inch over the temperature range) is small enough that the image displacement of the field stop on the detector active area is not detrimental to system performance. The bandpass filter is mounted to the prism/field stop/collimating lens cell for reason of ease of assembly.

The focusing lens is the environmental interface between the telescope interior and the HHLR interior. This lens is O-ring sealed to a lens cell which is, in turn, retained to the telescope housing.

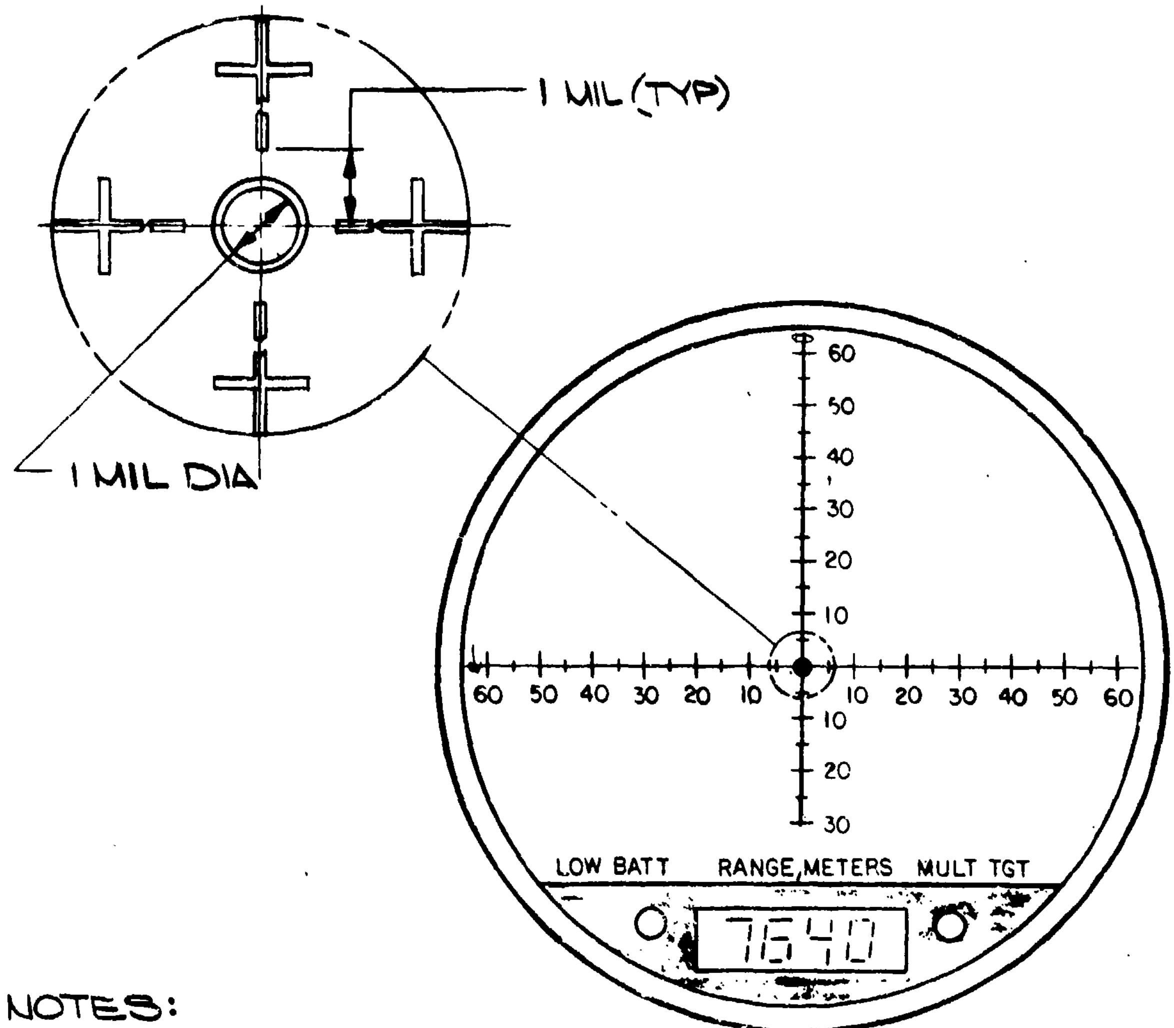
2.2.3 Display Optics, Reticle and Illumination

These three components of the telescope are related because of the commonality in the reticle plane. The reticle, of course, determines the sighting axis of the system, but it also provides other information. Figure 2-6 shows the proposed reticle configuration for the infantry version of the HHLR. The horizontal and vertical crosshairs are delineated every 5 artillery mils and are numbered every 10 mils. A small circle in the center defines the sighted target. The pattern is etched in the glass and filled with an opaque material.

The lower 20 mils of the reticle pattern is blacked out with windows in the mask for the rear projection of the display information. The black mask around this data provides a high contrast background for the LED's for any ambient scene brightness level. The data projected into focus in the reticle plane are: the minimum range set distance, the range to the target (using the same LED display digits), a low battery condition indicator LED, and a multiple target indicator LED. The LED subassembly providing this information mounts to the underside of the Optical Assembly and is discussed in paragraph 2.8.1.

The display array is reduced in size by a factor of two for presentation in the reticle plane. Two prisms and two lenses are required to transfer this image.

The reticle will be illuminated by a single replaceable incandescent bulb. Several experiments were conducted using LED illumination, with the LED's bonded to the reticle inside the telescope, but it was finally decided that use of a replaceable incandescent bulb is preferable for maintainability and EMI integrity. The bulb is mounted outside of the telescope housing and projects in to edge light the reticle through a red window in the housing. The window filters the light to eliminate radiation in the 10,648Å region. It also provides a red color to the reticle pattern to have least effect on operator's dark adaptation.



NOTES:

A. DIMENSIONS AND NUMERICAL MARKINGS SHOWN ARE IN ARTILLERY MILS (6400 MILS = 360°)

B. MARKINGS SHOWN ARE CORRECT READING AT 7X POWER, MARKINGS SHALL PROJECT INTO REAL FIELD WITHIN ± 2% OF MARKED VALUE IN MILS

C. ALL LINE THICKNESS TO BE 0.15 MILS $^{+0.1\ MIL}_{-0.0\ MIL}$

D. ALL NUMBER LINE WIDTHS TO BE 0.15 MILS $^{+0.15\ MIL}_{-0.00\ MIL}$

REV E

UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE: .XX ± .XXX ± FRACTIONS ± ANGLES ± ½°	SIZE A	CODE IDENT NO. 49671	2375195
	SCALE		SHEET 16

RCA 2408-3 (4-71) 7057

Figure 2-6. Reticle Pattern

2.2.4 Transmitter Telescope

The transmitter telescope is a four power Galilean design with a cemeted doublet objective lens and singlet negative eye lens. The telescope is designed to reduce the beam divergence of the laser transmitter module and to boresight the laser output to the laser receiver field stop. The raw beam laser output is expected to be 4 mm in diameter with less than 3.5 mr divergence. The output beam from the telescope will be 16 mm diameter with less than 0.90 mr beam divergence. Of this total 0.88 mr is attributed to the effect of geometric reductions and 0.02 mr is the effect of optical aberrations.

The transmitter telescope housing is part of the overall aluminum casting, well gusseted to minimize mechanical and thermal distortion. The housing surface around the eye lens provides the mechanical support and optical reference for the laser transmitter module. Dimensional control is maintained for concentricity and perpendicularity to the transmitter axis to allow interchangeability of laser modules without requiring realignment. A pilot diameter in the telescope housing centers the short precision lead diameter of the laser module to center the axes; the mating mounting surface perpendicular to the axis establishes parallelism between the laser and telescope axes.

The start pulse necessary to start the range counter is generated by a photodiode mounted in the transmitter housing wall. The photodiode detects scattered laser light between the eye lens and objective lens. The detector mounts externally and looks through a small window in the housing wall. The window keeps the telescope sealed and allows replacement of the detector without losing purge.

2.4 TRIGGER CIRCUIT MODULE

2.4.1 Packaging

The Trigger Circuit Module is located behind the battery compartment. This module includes the trigger circuit, dump circuit, inductor, trigger transformer, and two interlock switches. The larger components, such as the trigger transformer and inductor, are located on the front side of the board between the battery case and board. The remaining discrete components are packaged as a conventional type of printed wiring board design on the rear side of the board. Approximately 4.2 square inches of surface area are required for mounting the discrete components. The two interlock switches are mounted on the discrete component side of the board and are actuated by the HHLR cover.

This packaging approach was selected for maximum utilization of space available, to minimize lead lengths, and to minimize weight. The heavier components on the front of the board are bonded to the board with an RTV or urethane material. The board, in turn, is mounted to brackets extending from the battery compartment. The total weight of the Trigger Circuit Module including the inductor is 0.25 pounds.

The flashlamp trigger lead connections, inductor connections, and interlock switch lead connections are made using teflon insulated, stranded wire. All other electrical connections will be made using flexprint wire terminated at soldered terminals.

The trigger transformer output lead will be potted with an RTV material for high voltage arc-over protection. The entire board is coated with a urethane material for moisture protection.

2.4.2 Trigger Circuit Module Electrical Design

2.4.2.1 Description of Operation

The flashlamp trigger circuit is activated upon receipt of the "full charge" signal from the power supply circuitry, indicating that the storage capacitor of the pulse forming network (PFN) is fully charged and that the laser is ready to fire. The "full charge" signal is a positive step function having a rise time not exceeding one microsecond. It is developed from the emitter of a forward biased PNP transistor. As such, the off-state voltage will never quite reach ground due to $V_{ce\ sat}$, and accordingly, the off-state voltage is specified as +1.0 volt maximum. Due to power supply variations of ±5 percent, the peak of the "full charge" signal will vary between +11.4 volts and +12.6 volts, yielding a minimum step of +10.4 volts.

A maximum current drain limit of 1 mA has been placed on the "full charge" signal line in order not to load the +12 volt supply also used for the logic circuitry. A buffer circuit composed of Q_1 and Q_2 provides a high impedance input which is AC coupled to provide filtering and to reduce power consumption.

Q_1 is configured as an emitter follower with additional spurious noise filtering capability provided by the combination of R3 and C2. Capacitor C2 serves a dual function; it filters short term transients produced by Q_1, and also suppresses the dv/dt turn on transient for Q_2 by forming an attenuator network with the internal gate-to-anode capacitance of SCR Q_2.

Q_2 is utilized to provide a high speed trigger pulse to the main modulator (SCR) Q_3. The energy to fire Q_3 is stored in C3 during the charging interval. It is imperative to provide Q_3 with a stiff high speed gate voltage to ensure long term reliability and performance of Q_3. The high speed gate trigger insures that Q_3 is fully on when dissipating its nominal peak surge current of 40 amperes.

Capacitor C5 charges from the ramp voltage produced by charging the PFN. Upon receipt of the "full charge" signal, Q_3 conducts, discharging C5 and providing a 40 ampere current pulse to the primary of transform T1. The secondary of T1 provides a ringing under-damped pulse of 20,000 volts nominal. The secondary is coupled to the flash lamp by a quartz insulated lead parallel to the axis of the flash lamp. The high voltage starts ionization of the xenon in the flash lamp and the start of discharge of the PFN. Upon completion of the ranging interval sequence, the trigger circuit is capable of refiring within one second, maximum.

2.4.2.2 Input-Output Specs

2.4.2.2.1 Input Parameters

Battery Voltage

+30 volts maximum
+24 volts nominal
+20 volts minimum

PFN High Voltage

+800 volts maximum
+725 volts nominal
+600 volts minimum
(These voltage levels must be reached in one second, maximum.)

Full Charge Signal

+1.0 Volt	OFF STATE, maximum
12.6 Volts	ON STATE, maximum
12.0 Volts	ON STATE NOMINAL
11.4 Volts	ON STATE minimum

1.0 microsecond ON STATE RISE Time, maximum
1.0 mA LOAD CURRENT, maximum

2.4.2.2.2 Output Parameters

Flash Lamp Trigger Signal

30 kV maximum   20 kV nominal   12 kV mimimum

Flash Lamp Trigger Test Point

Amplitude - 4 volts, nominal
Pulse Width - 3 μsec, nominal
Rise Time - 0.5 μsec, nominal

2.4.2.3 Schematic

The schematic of the trigger circuit module is shown in Figure 2-14.

2.4.2.4 Parts List

C1	M39014/01-1219	R1	RCR05G104JM
C2	M39014/01-1464	R2	RCR05G103JM
C3	M39014/01-1461	R3	RCR05G301JM
C4	M39014/01-1443	R4	RCR05G101JM
C5	118P1059254	R5	RCR05G204JM
		R6	NS-1/2-1 OHM
		R7	RNC60H5112FM
		R8	RCR05G101JM
CR-1	JAN1N5554	R9	RNC70H1003FM
L2	MS-75088-5	R10	RNC70H1003FM
L1	MS-75084-06	R11	RCR32G203JM
Q1	JAN2N930		
Q2	JAN2N3028	T1	TR-1735C
Q3	S2600M		

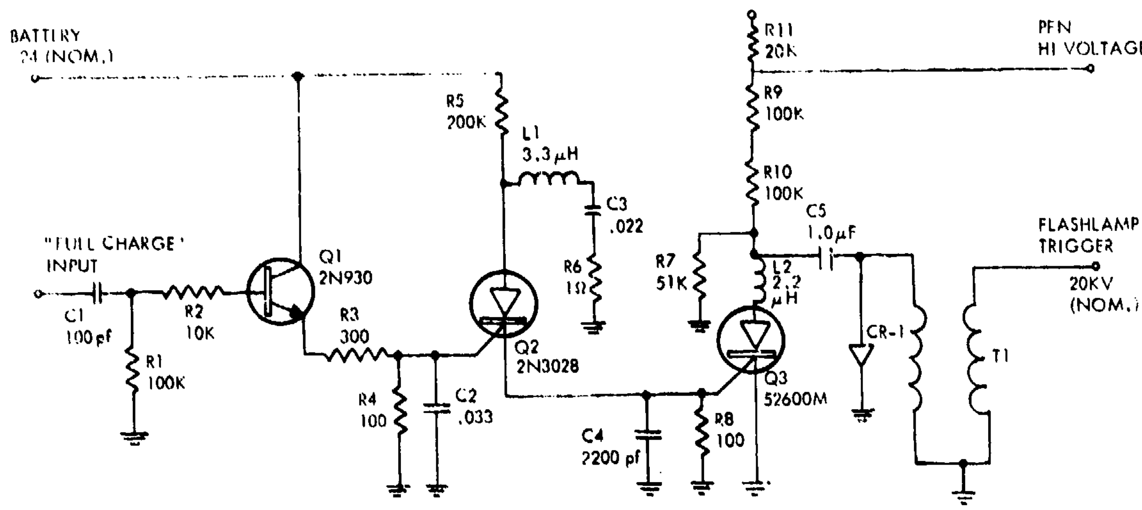


Figure 2-14. Trigger Circuit Module Schematic

2.4.3 Worst Case Performance

The input to the buffer stage is analyzed first to determine its worst case loading on the power supply circuitry. The load must not exceed 1 mA under worst case conditions.

Q_2 requires its maximum gate trigger current at cold temperatures. The minimum gate current required to fire all devices at -65°C is guaranteed to be 1.2 mA. In order to insure that the maximum area between the gate contact and cathode are turned on, a signal magnitude of ten times the minimum gate current is used as a design parameter, namely 12 mA. Absolute maximum rating on the gate current is 250 mA, peak. Coincidently, the maximum gate trigger voltage occurs at -65°C, and is specified at 1.1 volts, maximum.

Worst case tolerance on RCR05 resistors is taken as ±20 percent of initial value (±15 percent degradation after 3 yrs., plus ±5 percent initial purchase tolerance). R4 is then 80 ohms, and R3 is 240 ohms.

In order to meet the trigger voltage requirement of Q_2 at 1.1 volts, R4 must draw $\frac{1.1V}{80} = 13.75$ mA. The minimum current drawn through R_3 will then be 13.75 mA for R4, and 12 mA for the SCR trigger, for a total of 25.75 mA. The minimum h_{FE} for the 2N930 is 100 at -55°C. Base current will then be 25.75/100 = 0.26 mA. The input impedance seen looking into R2 is then

$$z_i = R2 + h_{ie} + (h_{fe} + 1)\, R_E$$

$$h_{ie} = v_{be}/i_b = \frac{0.8}{0.26 \times 10^{-3}} = 3K \text{ minimum}$$

$$Z_i = 8K + 3K + (101)\,(240 + 42) = 39.4K$$

The load on the input signal is then the parallel combination of Z_i with the 80K base current return resistor R1

$$\frac{(80 \times 39.4 \times 10^6)}{119.4 \times 10^3} = 26.4K$$

The maximum current drain on the maximum "full charge" signal is then obtained when the "full charge" signal is maximum, 12.6 volts

$$\frac{12.6}{26.4K} = 0.47 \text{ mA, peak}$$

Since the HHLR is required to operate only to -50°F, the above result is a very conservative estimate since the worst case semiconductor parameters were taken at -55°C and -65°C from available vendor data.

Under the same temperature conditions it can be shown that the gate trigger current will be supplied for a minimum input "full charge" signal. The input current in this case will then be $\frac{10.4V}{39.4K} = 0.263$ mA. A minimum h_{fe} of 100 guarantees a forced emitter current of at least 26.3 mA, 13.75 mA for R1, and the remaining 12.55 mA for the gate, which is 10.0 times the minimum guaranteed firing current.

The energy storage circuit of Q_2, C3, is designed to supply a nominal 0.5 microsecond 1 ampere pulse to the gate of Q3. The energy stored in C3 is proportional to the battery voltage squared, the value of R5, and the maximum forward blocking current of Q2, along with the value of C3.

The worst case battery voltage under which the system must operate is 20V. R5 may degrade to 240K, and C3 may degrade to 0.187μf. The voltage to which the capacitor will charge will be modified by the worst case forward blocking current. The 2N3028 specified a forward blocking current at 25°C and 150°C at a rated forward blocking voltage of 60 volts. Extrapolating to 46°C and 20 volts yields a maximum forward blocking current of 1.12μA. This provides a voltage drop of $(1.12 \times 10^{-6})\ (240 \times 10^{3}) = 0.27$ volts. The capacitor will therefore charge up to 19.7 volts. The energy stored in C3 is therefore

$$1/2\ CV^2 = (0.5)\ (0.0187 \times 10^{-6})\ (19.7)^2$$

$$= 3.62 \times 10^{-6} \text{ joules}$$

The peak current that can be supported by C3 and L1 is then derived

$$1/2\ CV^2 = 1/2\ LI^2$$

$$I = \frac{(CV^2)}{L}^{1/2} = \left[\frac{0.0187 \times 10^{-6}}{3.79 \times 10^{-6}} \times (19.7)^2\right]^{1/2} = 1.38A$$

The maximum rate at which a voltage is applied to the anode of Q2 must not exceed 100 volts/microsecond at 125°C. Minimum time constant of R5C3 is $(160 \times 10^3)(0.0187 \times 10^{-6}) = 2.9$ milliseconds. The maximum charge in one time constant would then be $0.63 \times 30 = 19$ volts. Maximum dv/dt for this combination is then

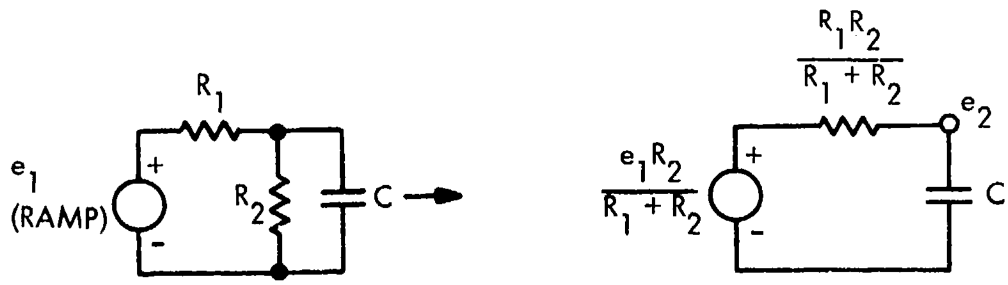
$$\frac{19 \text{ volts}}{2.9 \times 10^{-3} \text{ seconds}} \cong 0.007\text{V}/\mu\text{sec.}$$

insuring no faulty activations due to application of the battery voltage.

Q3 is designed to provide a 40 ampere pulse to the primary of transformer T1. The energy stored in C5 is dependent on the PFN voltage, the values of R7, R9, R10, and C5, and the maximum forward blocking current. In this case the forward blocking current produces only second order effects and will be disregarded. The worst case analysis is best approached by developing the nominal design details.

The input to the PFN network is assumed to be a linear ramp with a period of 1 second. The voltage to which C5 charges is determined by R7, R9, R10, and the ramping voltage.

The circuit may be transformed by taking a Thevinin equivalent as shown below.



Summing the currents at node e_2

$$\frac{(R_1 + R_2)(e_2) - e_1 R_2}{\dfrac{(R_1 R_2)(R_1 + R_2)}{R_1 + R_2}} + Cde_2 = 0$$

Let $R^* = \dfrac{R_1 R_2}{R_1 + R_2}$

where

R_1 = R9 + R10 on schematic

R_2 = R7 on schematic

$E_1(s) = \dfrac{V_1}{S^2}$ where V_1 is the maximum ramp voltage

$$E_2(s) = \frac{V_1/CR_1}{S^2\left(S + \frac{1}{R^*C}\right)} = \frac{V_1 R^*/R_1}{S^2} + \frac{VR^{*2}\, C/R_1}{S + \frac{1}{R^*C}} - \frac{VR^{*2}\, C/R_1}{S}$$

$$e_2(t) = \frac{V_1\ R^*T}{R_1} - \frac{V_1 R^{*2} C}{R_1} + \frac{V_1 R^{*2} C\ e^{-\frac{t}{R^*C}}}{R_1}$$

The voltage of interest is that at t = 1 second

The term on the right with the exponential produces second order effect at t = 1 sec and is disregarded.

The voltage on the capacitor is then

$$e_2(1) \quad \frac{V_1 R^*}{R_1} (1 - R^* C)$$

nominal values of $e_2(1)$ are then

$$e_2(1)_{nom} \quad \frac{V_1 R_2}{R_1 + R_2} \left(1 - \frac{R_1 R_2 C}{R_1 + R_2} \right)$$

$$e_2(1)_{nom} = \frac{V_1 (51 \times 10^3)}{200 \times 10^3 + 51 \times 10^3} \left[1 - \frac{(200 \times 10^3)(51 \times 10^3)(10^{-6})}{(200 \times 10^3) + (51 \times 10^3)} \right]$$

$$e_2(1)_{nom} = V_1 (0.194)$$

V_1	$e_2(\cdot)$
600	116
700	136
800	156

The worst case minimum voltage on the capacitor will occur when V_1 is 600, C is at its maximum, R is at its maximum, and R2 is at its minimum. Worst case degradation of the metal film resistors is ±2.5 percent, (±1 percent purchased tolerance, ±1.5 percent degradation after 3 years). Worst case degradation of the capacitor is ±15 percent (±10 percent initial purchase tolerance and a ±5 percent degradation after 3 years). Worst case resistor and capacitor values are then

	+2.5%	-2.5%	+15%	-15%
R_1	205×10^3	195×10^3	--	--
R_2	52.3×10^3	49.7×10^3	--	--
C	--	--	1.15×10^{-6}	0.85×10^{-6}

$$e_2(1)_{min} = \frac{(600)\,(49.7 \times 10^3)}{(205 \times 10^3) + (49.7 \times 10^3)} \left[1 - \frac{(205 \times 10^3)\,(49.7 \times 10^3)\,(1.15 \times 10^{-6}}{(205 \times 10^3) + (49.7 \times 10^3)}\right]$$

$$e_2(1)_{min} = 111.7 \text{ volts.}$$

The high voltage charging level on the capacitor will occur when V_1 is maximum, R_1 is minimum, R_2 is maximum, and C is minimum.

$$e_2(1)_{max} = \frac{800\,(52.3 \times 10^3)}{(195 \times 10^3) + (52.3 \times 10^3)} \left[1 - \frac{(195 \times 10^3)\,(52.3 \times 10^3)\,(0.85 \times 10^{-6})}{(195 \times 10^3) + (52.3 \times 10^3)}\right]$$

$$e_2(1)_{max} = 163.3 \text{ volts.}$$

An equivalent diagram of the flash lamp discharge circuit is shown in Figure 2-15.

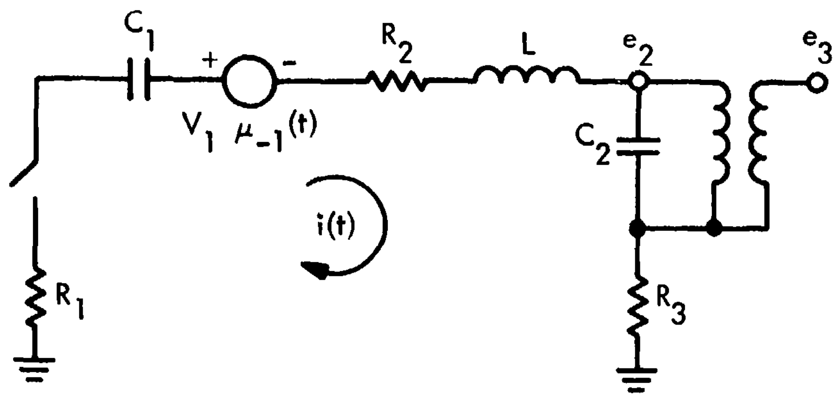


Figure 2-15. Flash Lamp Discharge Circuit

R_1 represents the worst case "on" resistance of Q_3. C_1 is the energy storage capacitor identified as C5 on the overall schematic, and the voltage generator $V_1\, u_{-1}(t)$ represents the charge on C_1. R_2 represents the transformer primary winding resistance, while R_3 represents the test point sampling resistor. C_2 represents the combination of load capacitance and interwinding capacitance reflected to the primary of the transformer. L_1 represents the primary winding leakage inductance.

Applying Kirckoff's law around the loop

$$R_1\, I(s) + \frac{I(s)}{SC_1} - \frac{V_1}{S} + R_2 I(s) + \frac{I(s)}{sC_2} + R_3\, I(s) + Ls\, I(s) = 0$$

$$I_{(s)} \left[\frac{1}{sC_1} + sL + R + \frac{1}{sC_2} \right] = \frac{V_1}{s}$$

where

$$R = R_1 + R_2 + R_3$$

$$I_{(s)} = \frac{V_1/L}{s^2 + \frac{R}{L}\, s + \frac{C_1 + C_2}{LC_1\, C_2}}$$

$$V_2(s) = \frac{I(s)}{sC_2} = \frac{V_1/LC_2}{s\left(s^2 + \frac{R}{L}s + \frac{C_1 + C_2}{LC_1\, C_2}\right)}$$

$$\frac{V_1/LC_2}{s\left(s^2 + \frac{R}{L}s + \frac{C_1 + C_2}{LC_1\, C_2}\right)} = \frac{V_1}{LC_2\left(\frac{C_1 + C_2}{LC_1\, C_2}\right)} \cdot \frac{W_n^2}{(s)\left(s^2 + 2\xi\, W_n s + W_n^2\right)}$$

$e_2(t)$ = primary voltage

$$e_2(t) = \frac{V_1}{LC_2\left(\frac{C_1 + C_2}{LC_1 C_2}\right)} \left[1 - \frac{1}{\left(1 - \xi^2\right)^{1/2}} e^{-\xi W_n t} \sin\left(W_n \left(1-\xi^2\right)^{1/2} t + \phi\right)\right]$$

where $\phi = \cos^{-1}\xi$.

$$W_n = \left(\frac{C_1 + C_2}{LC_1 C_2}\right)^{1/2}$$

$$\xi = \frac{R}{2L\,W_n}$$

$$\text{Time to peak} = t_p = \frac{\pi - \phi}{W_n \left(1 - \xi^2\right)^{1/2}}$$

$e_3(t) = Ne_2(t)$ where N = 200 turns

$$I(s) = \frac{V_1/L}{s^2 + \frac{R_s}{L} + \frac{C_1 + C_2}{LC_1 C_2}} = \frac{V_1}{L\left(\frac{C_1 + C_2}{LC_1 C_2}\right)} \left[\frac{W_n^2}{s^2 + 2\xi\, W_n s + W_n^2}\right]$$

$$i(t) = \frac{V_1\, W_n e^{-\xi W_n t} \sin W_n \left(1 - \xi^2\right)^{1/2} t}{L\left(\frac{C_1 + C_2}{LC_1 C_2}\right)\left(1 - \xi^2\right)^{1/2}}$$

i(t) will peak when $\sin W_n \left(1 - \xi^2\right)^{1/2} t$ is maximized, and will occur at multiples of $t = \frac{\pi}{2W_n \left(1 - \xi^2\right)^{1/2}}$.

The worst case minimum output pulse will occur under the following conditions:

(1) The charging voltage is at a minimum
(2) the storage capacitor value is at a minimum
(3) the effective primary shunt capacitance value is a maximum
(4) the primary leakage inductance value is a maximum
(5) the resistive losses are at a maximum

$$e_3(t)_{\text{min peak}} = \frac{(V_{1\,min})(N)}{L_{max}\,C2_{max}\left(\dfrac{C_{1\,min}+C_{2\,max}}{L_{max}\,C_{1\,min}\,C_{2\,max}}\right)}$$

$$\left[\frac{1 - e^{-\xi W_n t}\sin\left(W_n\left(1-\xi^2\right)^{1/2} t + \phi\right)}{\left(1-\xi^2\right)^{1/2}}\right]$$

$$L_{max} = 3.45 \times 10^{-6}$$

$$C_2\ max = 0.35 \times 10^{-6}$$

$$C_1\ min = 0.85 \times 10^{-6}$$

$$R_{max} = 0.35\ \text{OHMS}$$

$$W_n = \left(\frac{C_{1\,min}+C_{2\,max}}{L_{max}\,C_{1\,min}\,C_{2\,max}}\right)^{1/2}$$

$$= \left(\frac{0.85 \times 10^{-6} + 0.35 \times 10^{-6}}{3.45 \times 10^{-6} \times 0.85 \times 10^{-6} \times 0.35 \times 10^{-6}}\right)^{1/2} = 1.08 \times 10^{6}$$

$$\xi = \frac{R}{2L\,W_n} = \frac{0.35}{2 \times 3.45 \times 10^{-6} \times 1.08 \times 10^{6}} = 0.183$$

$$(1 - \xi^2)^{1/2} = \left(1 - (0.047)^2\right)^{1/2} = 0.998$$

$$\phi = \cos^{-1}\xi = \cos^{-1}(0.047) = 87.3° = 1.52 \text{ radians}$$

$$\text{voltage time to peak} = \frac{\pi - \phi}{W_n\left(1 - \xi^2\right)^{1/2}} = \frac{3.14 - 1.52}{(1.08 \times 10^6)(0.998)}$$

$$= 1.50 \times 10^{-6}$$

$$e_3(t)_{\text{min peak}} = \frac{(112)(200)(1 - \sin(\pi))}{(3.45 \times 10^{-3})(0.35 \times 10^{-6})(1.17 \times 10^{12})}$$

$$= 15866 \text{ volts.}$$

Minimum firing voltage established during test run no. 3 was at -65°F. This was for a primary voltage of 105 volts which is equivalent to 15 kW.

The worst case minimum gate drive current to Q_3 is calculated as fouows:

(1) Q_2 leakage current at its maximum = 5 μA

(2) L_1 is at its maximum (+15%) 3.8×10^{-6}

(3) C_3 is at its minimum (-15%) 0.0187×10^{-6}

(4) Battery voltage is at a minimum (20 volts)

(5) Resistive losses are at a maximum (2.9 Ω)

(6) Q_3 trigger voltage is at a maximum (1.5 volts)

An equivalent circuit of the switching interval is shown in Figure 2-19.

Summing voltage drops around the loop

$$I(s)\left[R + SL \frac{1}{SC}\right] - \frac{19}{s} + \frac{1.5}{s} = 0$$

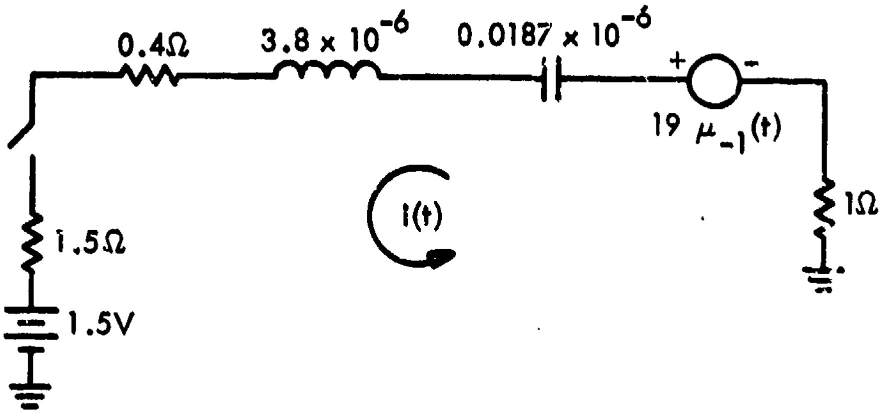


Figure 2-16. Equivalent Circuit of the Switching Interval

$$I(s) = \frac{17.5}{L} \left[\frac{1}{S^2 + \frac{R}{L}s + \frac{1}{LC}}\right] = \frac{17.5}{LW_n^2} \cdot \frac{W_n^2}{S^2 + 2\xi W_n S + W_n^2}$$

$$i(t) = \frac{17.5 \cdot e^{-\xi W_n t} \sin\left(W_n \left(1 - \xi^2\right)^{1/2} t\right)}{L W_n \left(1 - \xi^2\right)^{1/2}}$$

The current will peak when $\frac{di(t)}{dt} = 0$

$$0 = \frac{di(t)}{dt} = \frac{17.5}{L W_n} \left[- \xi W_n e^{-\xi W_n t} \sin\left(W_n \left(1 - \xi^2\right)^{1/2} t\right) + e^{-\xi W_n} W_n \left(1 - \xi^2\right)^{1/2} \cos\left(W_n \left(1 - \xi^2\right)^{1/2} t\right)\right]$$

$$\tan\left(W_n\left(1-\xi^2\right)^{1/2} t\right) = \frac{1-\xi^2}{\xi}^{1/2}$$

$$W_n = \left(\frac{1}{LC}\right)^{1/2} = \left(\frac{1}{3.8 \times 10^{-6} \times 0.0187 \times 10^{-6}}\right)^{1/2} = 3.75 \times 10^6$$

$$\xi = \frac{R}{2LW_n} = \frac{2.9}{2 \times 3.8 \times 10^{-6} \times 3.75 \times 10^6} = 0.101$$

$$\left(1-\xi^2\right)^{1/2} = \left(1-(0.101^2\right)^{1/2} = 0.994$$

$$\left(\frac{1-\xi^2}{\xi}\right)^{1/2} = \frac{0.994}{0.101} = 9.84$$

$$\tan^{-1} 9.84 = 84.2° = 1.47 \text{ radians}$$

$$W_n\left(1-\xi^2\right)^{1/2} t = 1.47$$

$$t_{peak} = \frac{1.47}{3.75 \times 10^6 \times 0.994} = 0.39 \times 10^{-6} \text{ seconds}$$

$$i(t)_{\substack{peak \\ min}} = \frac{17.5\, e^{-0.101 \times 3.75 \times 10^6 \times 0.39 \times 10^{-6}} \sin\left(3.75 \times 10^6 \times 0.994 \times 0.39 \times 10^{-6}\right)}{3.8 \times 10^{-6} \times 3.75 \times 10^6 \times 0.994}$$

$$= 1.06 \text{ amperes}$$

The maximum current to gate drive to Q_3 will occur under the following conditions:

(1) L_1 is at its minimum value (-15%) 2.8×10^{-6}

(2) C_3 is at its maximum value (+15%) 0.025×10^{-6}

(3) The battery voltage is at a maximum (+30 volts)

(4) Resistive losses are at a minimum 2.4 Ω

(5) Leakage of Q_2 is at a minimum (negligible)

(6) Q_3 trigger voltage is at a minimum (0.65 volts)

An equivalent circuit of the switching interval is shown in Figure 2-17.

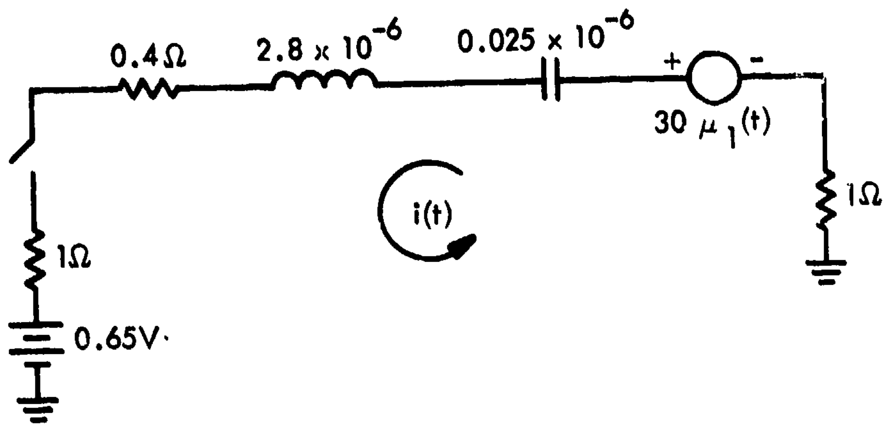


Figure 2-17. Equivalent Circuit of the Switching Interval

Summing voltage drops around the loop

$$I(s) = \frac{29.35}{LW_n^2} \cdot \frac{W_n^2}{S^2 + \frac{R}{L}W + \frac{1}{LC}}$$

$$W_n = \left(\frac{1}{LC}\right)^{1/2} = \left(\frac{1}{2.8 \times 10^{-6} \times 0.025 \times 10^{-6}}\right)^{1/2} = 3.78 \times 10^6$$

$$\xi = \frac{R}{2L W_n} = \frac{1}{2 \times 2.8 \times 10^{-6} \times 0.025 \times 10^{-6}} = 0.113$$

$$\left(1 - \xi^2\right)^{1/2} = \left(1 - (0.113)^2\right)^{1/2} = 0.993$$

$$\frac{\left(1 - (\xi)^2\right)^{1/2}}{\xi} = \frac{0.993}{0.113} = 8.78$$

$$\tan^{-1} 8.78 = 83.5° = 1.45 \text{ radians}$$

$$t_{peak} = \frac{1.45}{3.78 \times 10^6 \times 0.993} = 0.388 \times 10^{-6} \text{ seconds.}$$

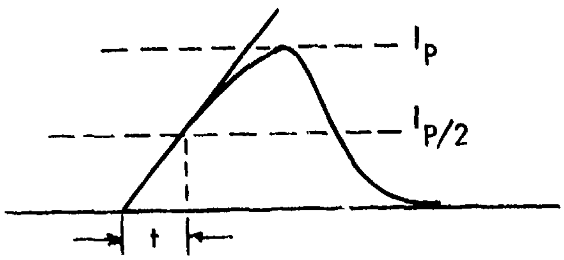
$$i(t)_{peak\ max} = \frac{29.35\, e^{-0.113 \times 3.78 \times 10^6 \times 0.388 \times 10^{-6}} \sin(3.78 \times 10^6 \times 0.993 \times 0.399 \times 10^{-6})}{2.8 \times 10^{-6} \times 3.78 \times 10^6 \times 0.993}$$

$$= 2.32 \text{ amperes.}$$

These results indicate that the fastest turn-on off Q3 will occur over the worst case conditions without overstressing or underdriving the unit.

In order to insure that Q_3 is not overstressed due to the high in-rush currents which occur when the device is just turning on, the maximum rate of change of on-state current, $\frac{di}{dt}$, must not exceed 200 amperes per microsecond. This quantity is defined as the peak surge current divided by two times the time interval required to reach half the peak surge current.

$$\frac{di}{dt} = \frac{I_{peak}}{2t} \text{ where } t = \text{time to } \frac{Ip}{2}$$



The maximum surge current will occur under the following conditions:

(1) Charging voltage is at a maximum (164 volts)

(2) Inductance values are at a minimum

(3) C_5 value is at a maximum

(4) Interwinding and shunt capacitance of the transformer reflected to the primary is at a minimum.

(5) Resistive losses are at a minimum.

A diagram of the switching interval is shown in Figure 2-18.

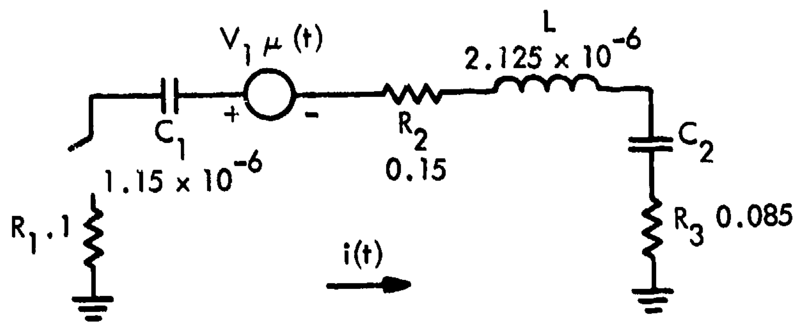


Figure 2-18. Switching Interval Diagram

$R = R_1 + R_2 + R_3 = 0.335\Omega$

$L = 2.125 \times 10^{-6}$

$C_1 = 1.15 \times 10^{-6}$

$C_2 \quad 0.26 \times 10^{-6}$

$V_1 \quad 164$ volts

Summing around the loop and collecting terms,

$$I(s) = \frac{V_1 + C_1 \times W_n^{\,2}}{\left(C_1 + C_2\right)\left(S^2 + 2\xi W_n + W_n^{\,2}\right)}$$

$$W_n = \left(\frac{C_1 + C_2}{LC_1\, C_2}\right)^{1/2} = \left(\frac{1.41 \times 10^{-6}}{6.35 \times 10^{-19}}\right)^{1/2} = 1.34 \times 10^{6}$$

$$W_n 2 = 1.79 \times 10^{12}$$

$$\xi = \frac{R}{2L\,W_n} = \frac{0.335}{(2)\left(2.125 \times 10^{-6}\right)\left(1.34 \times 10^{6}\right)} = 0.058$$

$$\left(1-\xi^2\right)^{1/2} = 0.996$$

$$C_p = \frac{3.14}{2 \times 1.34 \times 10^{6} \times 0.996} = 1.17 \times 10^{-6} \text{ seconds}$$

$$C(t) = \frac{V_1\, C_1}{C_1 + C_2} \cdot \frac{W_n e^{-\xi W_n t} \sin\left(W_n \left(1-\xi^2\right)^{1/2} t\right)}{\left(1 - \xi^2\right)^{1/2}}$$

$$i(t)_{\substack{\text{peak}\\ \text{max}}} = \frac{1.64 \times 1.15 \times 10^{-6}\, e^{-0.058 \times 1.34 \times 10^{6} \times 1.17 \times 10^{-6}} \sin(\pi/2)}{1.41 \times 10^{-6} \times 0.996}$$

$$= 122 \text{ amperes.}$$

The current reaches half the peak value of 122 amperes at $t = 0.36 \times 10^{-6}$ seconds

Substituting into the $\frac{di}{dt}$ formula,

$$\frac{di}{dt}_{max} = \frac{122}{(2)\ (0.36 \times 10^{-6})} = 169 \text{ amperes}/\mu\text{sec.}$$

Hence, under maximum worst case conditions the circuit will not exceed the absolute maximum specification of 200 amperes/μsec.

2.4.4 Breadboard Test Data

2.4.4.1 Bench Tests

Initial design of the trigger circuit was predicated on the use of the +24-volt battery supply utilizing an EG&G TR-1735A low voltage step-up transformer. Tests showed that the transformer could not generate secondary voltages within the 20 to 30-volt primary input range to reliably trigger the flash lamp. Internal arc over was observed at approximately 18 kV. The low voltage primary approach was abandoned, and a high voltage USCI transformer was utilized. This unit had a 150:1 winding ratio which required 200 volts on the primary to produce a 20 kV secondary output. Internal arc-over was observed at voltages over 22 kV.

A third unit, EG&G TR-1735B was tested which proved to be satisfactory in all respects. This unit has a 200:1 winding ratio which allows a lower primary voltage. This in turn allows the energy storage capacitor C5 to be purchased in the smaller 200V package resulting in a 2/1 space saving. This unit will produce a 14 kV secondary output with a charging voltage on the primary of 100V, and 25 kV secondary output with a primary charging voltage of 165 volts.

The bleeder network for the energy storage capacitor was initially designed with a 150V zener diode. Analysis of the circuit for worst case conditions showed that a resistive divider circuit was capable of providing the necessary operating point stability, and the zener diode was replaced.

2.4.4.2 Temperature Tests

Temperature tests were conducted on the preliminary breadboard utilizing a TR-1735B transformer. Two different tests were conducted; the first utilizing a resistive divider, and the second utilizing a zener diode. The test results are tabulated below for the resistive divider where the charging voltage was manually adjusted by varying the power supply voltage. The second run utilized a zener diode where the charging voltage was allowed to seek its own equilibrium point as the temperature was varied.

Ambient 78°F — Run No. 1

	Flash Lamp Trigger Voltage	Primary Voltage
	18 kV	135 volts
	20 kV	150 volts
	21 kV	165 volts

minimum "full charge" trigger voltage = 5.2V, t_t = 2 μsec

-55°F	18 kV	135
	19.5 kV	150
	21.0 kV	165

minimum "full charge" trigger voltage = 7.2V, t_r = 2 μsec

+165°F	17 kV	135
	18.5 kV	150
	20 kV	165

minimum "full charge" trigger voltage = 3.6V, t_r = 2 μsec

The above data was taken at temperature extremes, 5°F beyond those specified, to eliminate marginality.

Run No. 2

Temp	"Full Charge" Volt	Flash Lamp Trigger Voltage	Zener Voltage
78°F	5.2V	21.5 kV	151V
-60°F	7.2V	21.0 kV	140V
+165°F	3.6V	20.0 kV	157V

Again, temperature extremes were extended by 5°F at the cold temperature, and +10°F at the hot temperature.

A third temperature run was made with the trigger circuit driving a flash lamp. The flash lamp tested was an EG&G 650 torr Xenon lamp, FXP-35-1.18 with glass to metal seals; the step-up transformer was a TR-1735C, a more compact version of the TR-1735B used in the first two temperature runs. This temperature test was undertaken to determine the minimum firing conditions of the flash lamp.

Run No. 3

Temperature	Minimum Primary Voltage	Secondary Voltage	PFN Voltage, Min
Ambient, 74°F	90V	14 kV	600V
-65°F	105V	15.5 kV	550V
+165°F	100V	15 kV	600V

The temperature run was again run beyond the specified limits to eliminate any possibility of marginality at the specified limits. The tests indicate that the trigger circuit will function over the worst case operating conditions.

2.5 DETECTOR-PRE-AMPLIFIER MODULE

2.5.1 Packaging

The Detector/Pre-Amplifier Module is a low profile TO-8 transist(package which contains the receiver detector and its preamplifier circuitry. The silicon avalanche photodetector is bonded to a single alumina hybrid preamplifier substrate. This substrate is soldered to the feed through pins of the 12-lead hermetic header. The distance between the substrate and the header is in the order of 0.002-inch nominal. A special low profile TO-8 can with transparent window is welded to the header to complete the package. The window is induction melted and fused to the stainless steel can. Only the central 0.06-inch diameter of the window is actually used and this area is maintained optically flat and parallel. The window is antireflection coated peaked at 1.06μ wavelength to minimize energy loss.

The actual alignment of the focused laser energy on the detector is fairly critical. The nominal spot size of the re-imaged receiver field stop on the 0.032-inch diameter detector active area is 0.008-inch diameter. However, the sensitivity of the detector is not linear across the diameter -- the gain is greatest in the center region -- so it is important to center on the detector as well as possible. In addition, temperature effects upon the collimating and focusing lenses and their mounts introduce defocusing at the detector, and temperature effects upon the receiver telescope cause some shift of the field stop relative to the detector. The net result of these environmental effects means the detector should be positioned at assembly to within about 0.001-inch concentricity and 0.002-inch axially with respect to the focusing lens. The alignment of the detector to the module with these tolerance extremes is not economically feasible if at all possible. Therefore, to make the detector/preamplifier module directly interchangeable at the system level without realignment, the module is optically positioned in an intermediate cell mount to the required tolerances and bonded in place. This cell is then interchangeable with any rangefinder. The actual positioning of the detector in the module is shown in Figure 2-19.

Since the 12-lead header is symmetrical, the module cell will be keyed to the telescope so that the detector cannot be incorrectly wired to the flexible printed cable.

The module cell will be finished with an electrically conductive iridite and bonded to the detector module with electrically conductive adhesive to prevent EMI leakage through the telescope to the outside of the HHLR.

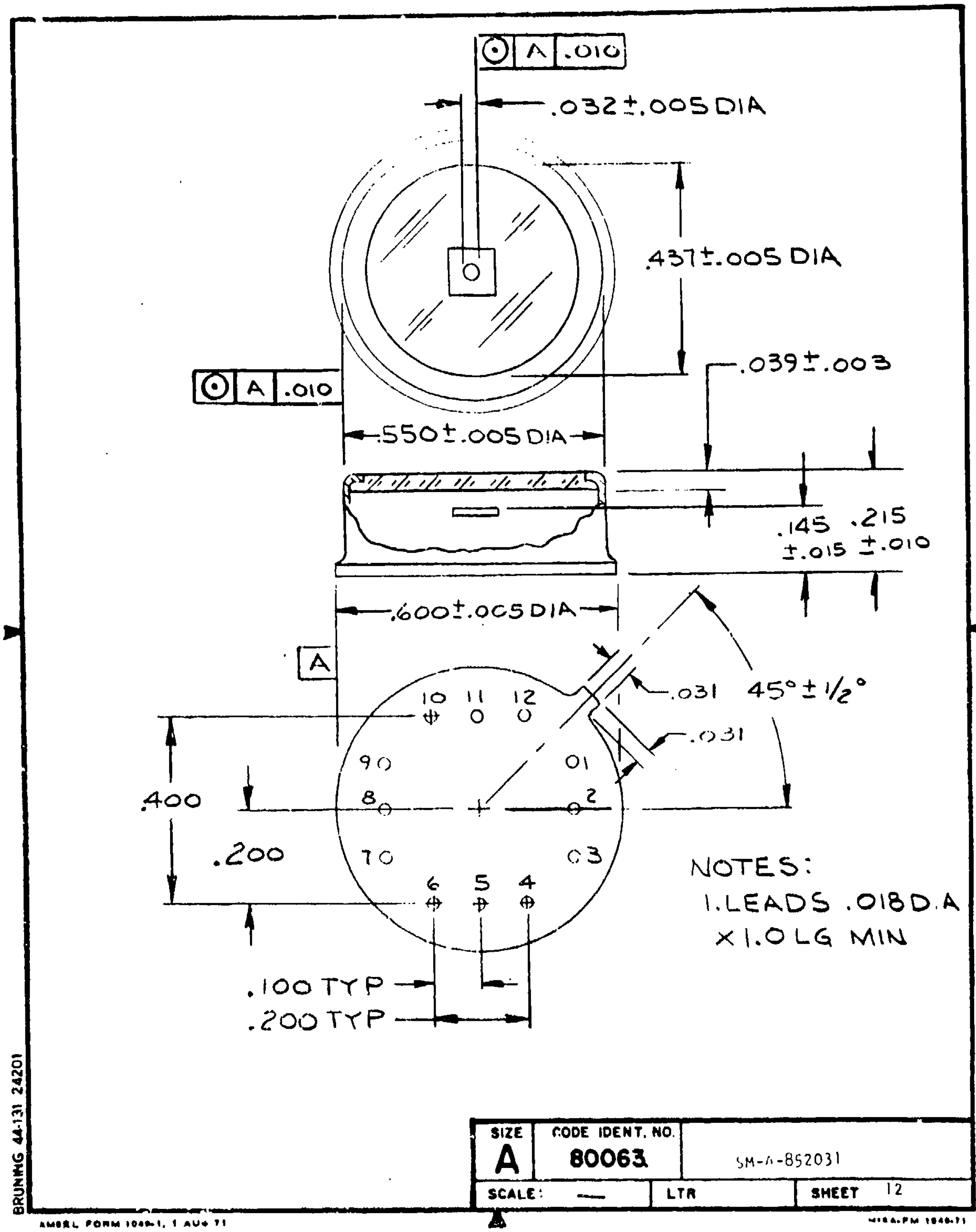


Figure 2-19. Physical Dimensions

2.5.2 Electrical Design

2.5.2.1 Description of Operation

The Detector Pre-Amplifier shown in Figure 2-20 is a standard positive feedback amplifier used for avalanche diode applications. It consists of a reach through avalanche diode (similar to the commercially available RCA C30817) and a low noise unity gain preamplifier.

The preamplifier consists of one D-MOS FET (Q_1) operated as a source follower with substantially unity voltage gain, providing positive feedback to detector D_1 thus reducing the effective input capacitance to enhance the bandwidth capability. A parts list for the preamplifier is presented in Table 2-7.

Q_2 and Q_3 operate as emitter followers to reduce the output impedance. The emitter of Q_2 is fed back to the substrate of Q_1 to reduce interelectrode capacitance of input FET Q_1. The values of the bias resistors R_3, R_4, R_5 have been selected for low voltage and low power operation.

The noise contribution from the preamplifier, exclusive of the diode and load resistance, is approximately 6×10^{-9} $V/\sqrt{Hz}$ for a diode load resistor of 22 KΩ.

The diode load resistor will be 22 KΩ to provide a minimum responsivity of 4.4×10^5 V/W for the APD - preamplifier combination.

2.5.2.2 Input-Output Specifications

Inputs: The APD-Preamplifier combination shall have a minimum responsivity of 4.4×10^5 V/W when measured with an APD gain of 100. The rise time shall be not more than 40 nanoseconds and fall time not more than 40 nanoseconds.

The APD and Preamplifier in combination shall have a maximum room temperature NEP of 10^{-13} and at +70°C the NEP shall not exceed 2×10^{-13} under dark conditions.

The APD detector preamplifier shall draw less than 10 milliamperes at ±12V and require a high voltage between +150V and +550V at less than 5 μa.

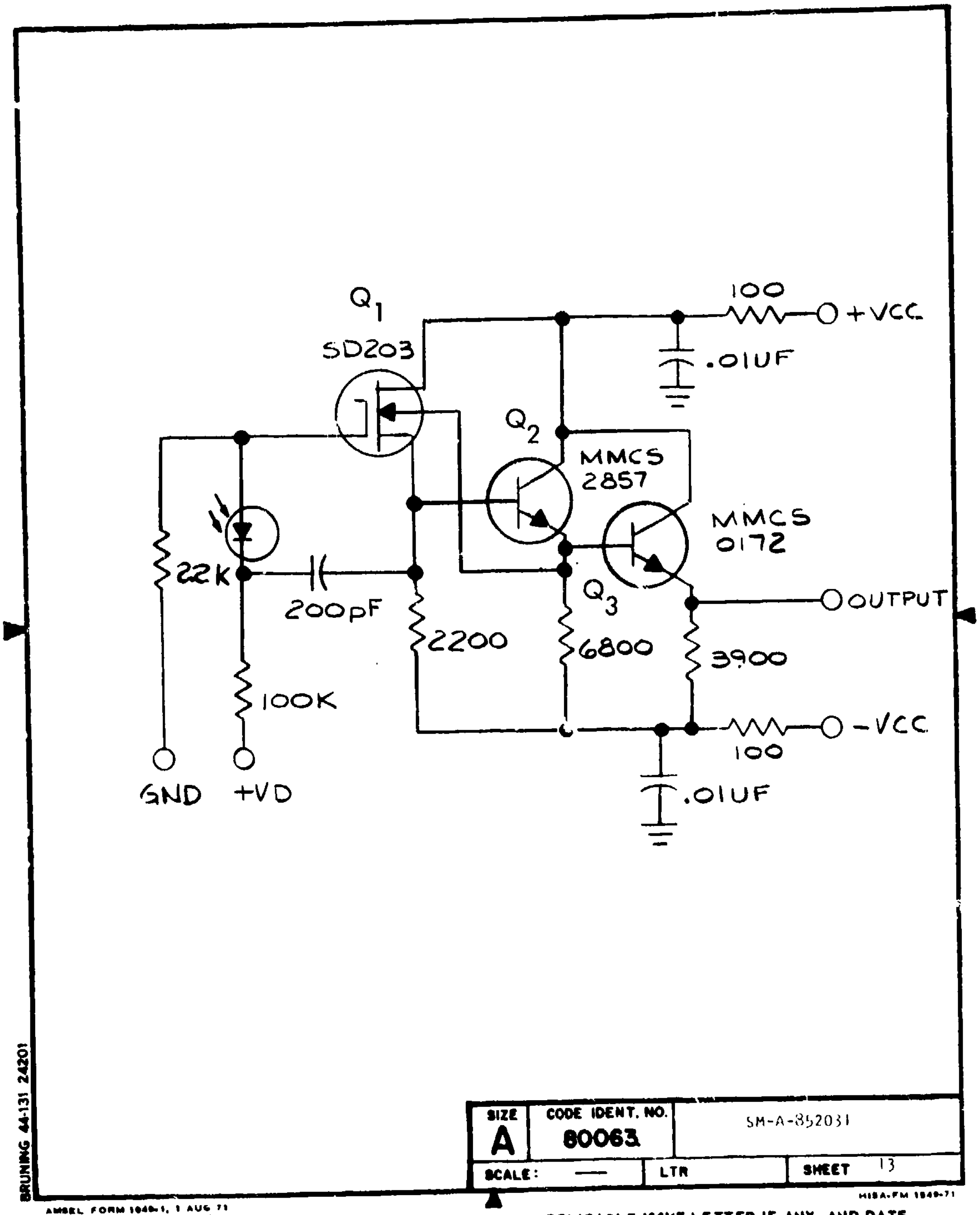


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Figure 2-20. Preamplifier Schematic Diagram

Table 2-7. Preamplifier Parts List

R_1	22K
R_2	100K
R_3	2.2K
R_4	6.8K
R_5	3.9K
R_6	100Ω
R_7	100Ω
C_1	200 pf
C_2	0.01μf
C_3	0.01μf
Q_1	SD203
Q_2	MMCS2857
Q_3	MMCS0172
D_1	Equivalent to C30817

2.5.3 Bench Tests

Several breadboards of the preamplifier have been built and tested at room temperature. The rise time, fall time, and NEP have been checked and meet the specifications. The pulse responsivity test pends completion of a calibrated signal source which is under construction. The AGC loop has been closed using a commercial high voltage power supply and the Wilmore supply.

2.5.4 Electrical Analysis

The DC bias conditions for the preamplifier are as follows:

With negligible gate current from Q_1 and negligible dark current from the APD, the gate of the D-MOS device (Q_1) will be at zero volts. If the maximum gate to source voltage of 2.0 volts is used, the bias current in Q_1 is

$$I_{bias} = (V_S - V_T)/R3$$

$$I_{bias} = (12.0 - 2.0)/2.2K$$

$$I_{bias} = 4.5 \text{ ma}$$

At this bias level the transconductance is 8000 μmhos. The gain of the first source follower is

$$A = gm\ R_2$$

$$= 8 \times 10^{-3} \times 2.2 \times 10^{3}$$

$$= 17.6$$

The Input capacitance to Q_1 and the APD diode capacitance are both reduced by the neutralization factor $1/(1 + gm\ R_2)$.

Assuming a total capacitance of 3.5 pf for both the diode and the DMOS input the neutralization factor reduces this to 0.20 pf. The total capacitance including stray capacitance that is not neutralized is estimated to be 0.75 pf in the hybrid package where lead lengths are short and terminals are not required for component mounting.

With the minimum voltage (-2V) on the source of Q_1 and assuming an 0.8V V_{be} of Q_2, the minimum bias in Q_2 is

$$i_{bias} = \left|V_S - V_T - V_{bE_1}\right| / R_4$$

$$I_{bias} = \left[+12.0 - 2.8\right] / 6800$$

$$\cong 1.4 \text{ ma}$$

Assuming a V_{be} of 0.8V for Q_3 yields a bias current of

$$I_{bias} = \left(V_S - V_T - V_{be_1} - V_{be_2}\right) / R5$$

$$I_{bias} = (+12.0 - 2 - 0.8 - 0.8)/3900$$

$$= 8.4/3900$$

$$= 2.2 \text{ ma}$$

Using the above value of gm = 8000 (worst case) and C_d = 3 pf. a graphical analysis was done to predict the performance of the preamplifier for the purpose of determining the value of K_e used as the electronic processing ratio in the video amplifier analysis. The results of this analysis are shown in Figure 2-21.

Figure 2-21 shows the calculated response to a 4.5 nanosecond pulse with a 2.5 nanosecond rise and 5 nsec fall time. The avalanche photodiode was simulated using a trapozoidal current source of 1 A/W and the diode load resistance (R1) was 22K shunted with an effective neutralized capacitance of 0.9 pf. The theoretical response of the preamplifier is shown as the output curve of Figure 2-21. Its peak is approximately 0.18 A/W which yields a K_e of 0.18.

2.6 VIDEO AMPLIFIER - AGC MODULE

2.6.1 Packaging

The Video Amplifier - AGC Module is a hybrid circuit packaged on a 2.25 by 1.25 by 0.035-inch alumina substrate. The total weight of the module is 0.04 pounds. Active chip devices will be mounted within a custom or H.I.P. hermetically sealed enclosure but resistors and capacitors may be internal or external to this enclosure. Available beam-lead devices will be used where possible since they are integrally hermetically sealed (Si_3N_4), which will reduce the required seal enclosure on the hybrid substrate.

The Video Amplifier - AGC Module is mounted to four machined bosses on the telescope housing as shown in Figure 2-23.

The mounting design employs two clips located along the forward edge of the substrate. The opposite edge will be held against resilient pads, bonded to optical assembly, by two-tabs. The hardware is conventional screws and washers.

The compliance of this mounting method precludes stresses inducing significant bending in the substrate.

Electrical connections to and from the module are made using flexprint wiring terminated at soldered pins.

The entire assembly is conformally coated with a urethane material for moisture protection.

The hybrid approach was selected over a standard printed wiring board with discrete components design because of size and weight savings, as well as minimized handling, assembly, and test requirements.

2.6.2 Electrical Design

2.6.2.1 Description of Operation

A schematic of the Video Amplifier-AGC module is shown in Figure 2-24 and the corresponding parts lists in Table 2-8.

The Video Amplifier-AGC Module receives both the APD shot noise and target return pulses from the preamplifier. The APD shot noise is processed to set the operating point of the APD diode. The target return pulses are detected and used to stop the range counter.

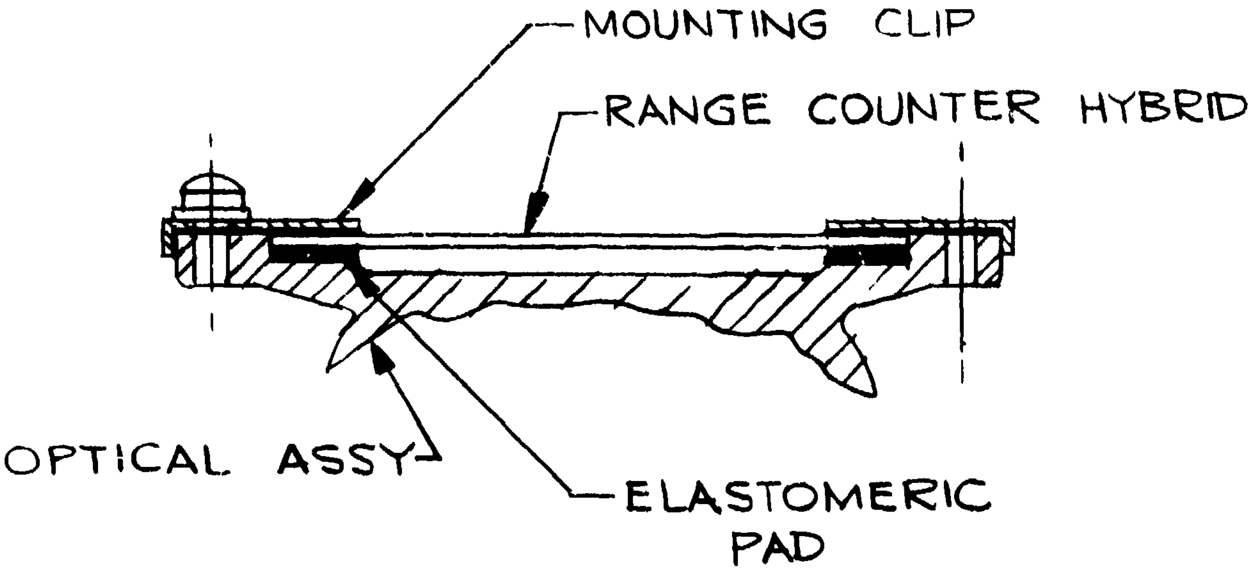
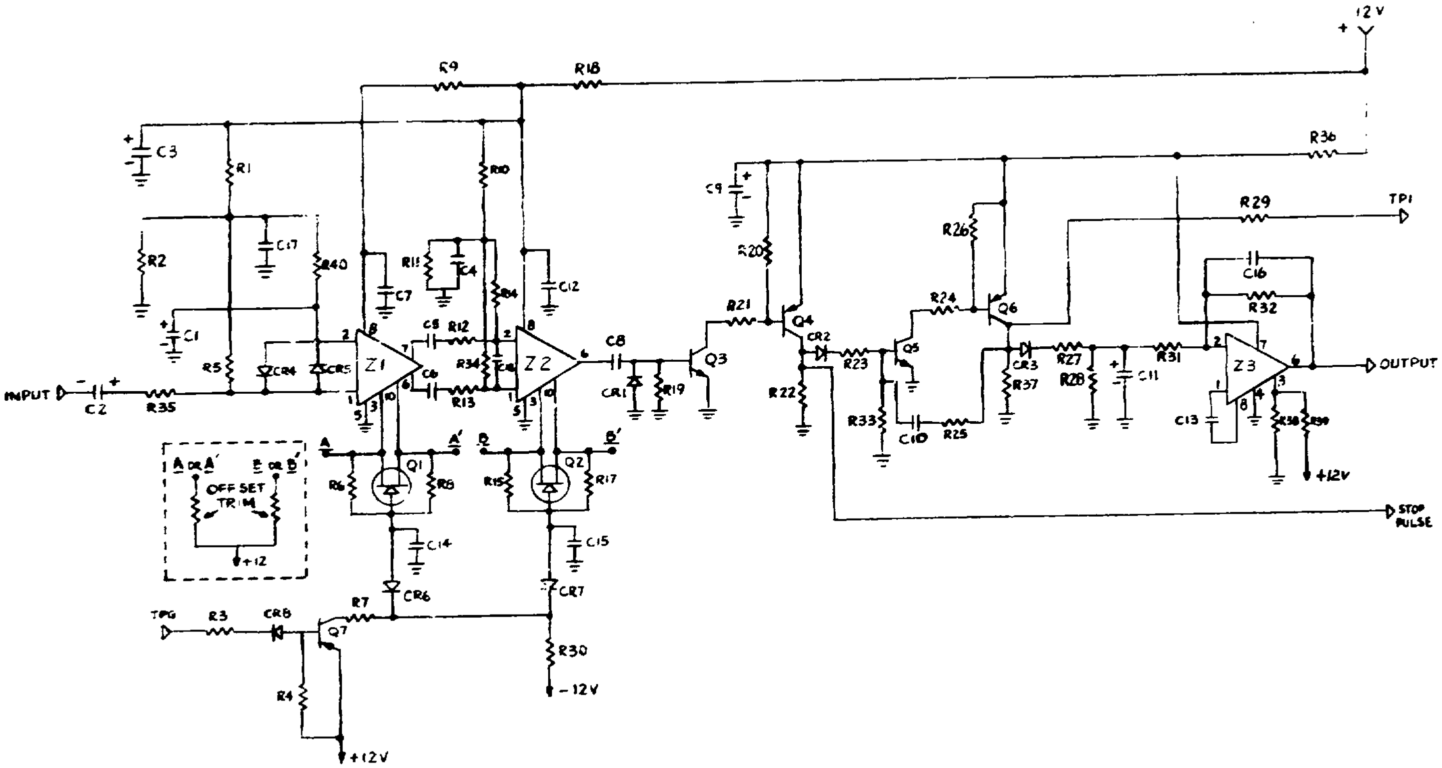


Figure 2-23. Video Amplifier Mounting

The Video Amplifier-AGC Module contains three primary circuit functions: the video amplifier and TPG, the threshold, and the avalanche photodiode AGC circuit.

The Video Amplifier is a two stage (Z_1 and Z_2) wide band, fast recovery amplifier with a fixed gain for signal returns from targets between the ranges of one and ten kilometers. The gain of the video amplifier is set so that the total system noise from sources other than the APD will not contribute significantly to the TCR during the closed loop AGC period prior to ranging and yet provide sufficient gain to produce a probability of detection of 99% on minimum signal levels during ranging.

The Video Amplifier contains a time programmed gain (TPG) circuit which prevents atmospheric backscatter of laser energy at close ranges (less than



REF DE	CAP VALUE	PART NO.
C1	.47µF	
C2	.47µF	
C3	22µF	
C4	.01µF	
C5	100PF	
C6	100PF	
C7	.01µF	
C8	0.1µF	
C9	22µF	
C10	5000PF	
C11	22µF	
C12	.01µF	
C13	150PF	
C14	91PF	
C15	150PF	
C16	4.7µF	
C17	1000PF	
C18	[illegible]PF	
CR1		1N4148
CR2		1N4148
CR3		1N4148
CR4		1N4148
CR5		1N4148
CR6		1N4148
CR7		1N4148
CR8		1N4148
Q1		2N4391
Q2		2N4391
Q3		2N2369
Q4		2N3546
Q5		2N2369
Q6		2N2907
Q7		2N2907
Z1		MC1733CL
Z2		MC1733CL
Z3		CA3130T

Figure 2-21. Video Amplifier Schematic

Table 2-8. Video Amplifier Parts Lists

RESISTOR NUMBER	NOMINAL VALUE	MINIMUM VALUE	MAXIMUM VALUE	RESISTIVITY	LENGTH	WIDTH
R35	51 OHMS	51 OHMS	62 OHMS	100 OHMS	25	50
R9	100 OHMS	95 OHMS	105 OHMS	100 OHMS		
R18	100 OHMS	95 OHMS	105 OHMS	100 OHMS		
R36	100 OHMS	75 OHMS	125 OHMS	100 OHMS	30	33
R21	220 OHMS	176 OHMS	264 OHMS	100 OHMS	60	32
R5	510 OHMS	459 OHMS	561 OHMS	100 OHMS	75	60 TOP HAT
R20	510 OHMS	408 OHMS	612 OHMS	100 OHMS	75	60 TOP HAT
R27	510 OHMS	383 OHMS	637 OHMS	100 OHMS	75	60 TOP HAT
R7	2000 OHMS	1900 OHMS	2100 OHMS	5000 OHMS	25	52
R22, 29	2000 OHMS	1500 OHMS	2500 OHMS	5000 OHMS	25	52
R25	3900 OHMS	3820 OHMS	3980 OHMS	5240 OHMS	25	34
R23	5100 OHMS	3820 OHMS	6380 OHMS	5000 OHMS	30	33
R1	5100 OHMS	4850 OHMS	5360 OHMS	5000 OHMS	45	33
R2	5100 OHMS	1 X R1	5%	5000 OHMS	45	35
R10	5100 OHMS	1 X R1	5%	5000 OHMS	45	35
R11	5100 OHMS	1 X R10	5%	5000 OHMS	45	35
R30	7500 OHMS	7120 OHMS	7880 OHMS	5000 OHMS	45	32
R3 R4 R19 R24 R26 R33 R37	10K OHMS	9000 OHMS	10K OHMS	5000 OHMS	52	32
R28	100K OHMS	90K OHMS	110K OHMS	100K OHMS	30	33
R31	33K OHMS	31.3K OHMS	34.7K OHMS	100K OHMS	25	70
R32	330K OHMS	10 X R31	5%	100K OHMS	75	28
R39	76K OHMS			100K OHMS	25	50
R38	50K OHMS			100K OHMS	30	35
R6	100K OHMS	95K OHMS	105K OHMS	100K OHMS	30	33
R8	100K OHMS	1 X R6	5%	100K OHMS	30	35
R15	100K OHMS	1 X R6	5%	100K OHMS	30	35
R17	100K OHMS	1 X R15	5%	100K OHMS	30	35

1000 meters) from exceeding the video amplifier threshold and generating false target returns. The TPG circuit operates as follows. During the flash lamp period, a 60 microsecond gate is applied to the video amplifier which reduces its gain by approximately 30 dB. After the laser fires, the TPG gate is removed and the video amplifier gain starts increasing to its full gain, which it reaches in about 6.7 microseconds, corresponding to a 1000 meter range.

The output of the video amplifier drives a threshold circuit. This circuit produces output pulses each time the input voltage exceeds a preset level. The system threshold is set so that pulses with a S/N ratio of greater than 6.98 will have a probability of detection of greater than 99% with a system FAR of less than one false alarm per 100 range tries.

Target returns (and false alarm noise pulses) which exceed the threshold are stretched to 40 nanoseconds and constitute stop pulses to the range counter.

During the AGC loop operation, noise pulses which exceed the threshold, drive the avalanche photo diode AGC circuit. This circuit constitutes a pulse counter with a dc output voltage that is fed to the APD power supply. This control voltage sets the APD operating point close to its characteristic "knee".

The knee of the APD diode is used during AGC operation rather than the normal operating point since at low temperatures, a low NEP preamplifier will not produce sufficient noise (with a reasonable gain) to keep the APD diode within its normal operating range. The AGC circuit contains a 70 micro-second one shot that is triggered when noise pulses exceed the threshold. The output of the one-shot is converted to a dc voltage in an averaging circuit. This dc voltage is then compared to a reference voltage derived from the regulated +12 vdc by a resistive divider. The difference between the averaged dc voltage and the reference voltage is amplified in a differential amplifier and constitutes the AGC control voltage to the APD power supply.

During the approximately one second before ranging, the AGC loop sets the APD voltage close to the knee of the APD operating curve. Upon the initiation of the ranging cycle, a circuit in the APD power supply uses the full charge signal to turn off the APD high voltage oscillator. The high voltage is stored on the output capacitors due to the high impedance load and back biased rectifier diodes. At the same time, a small current is drawn through a resistor in series with the APD and reduces its voltage to place the operating voltage 3.5% ± 0.5% below the avalanche knee of the APD curve. An additional drop, due to the discharge of the high voltage during the ranging sequence, is controlled to less than 0.5%.

2.6.2.2 Input-Output Specification

The video amplifier accepts the following inputs:

(1) TPG Gate - A logic 1 level pulse coincident with the full charge signal; returns to a logic 0 coincident with start pulse. A logic 1 level is a voltage level of 12V ±5 percent connected through a 250 Ω source impedance. A logic zero is the equivalent of a 250Ω resistive load to ground.

(2) Video Input - The video amplifier will accept an input signal up to +15 volts in amplitude.

(3) Power Supply - The video amplifier requires -12 VDC ±5% at 3.0 ma and +12 VDC ±5 percent @ 25 ma.

The video amplifier produces the following outputs.

(1) Stop Pulse - The stop pulse is a logic 1 pulse having the following characteristics. (A logic 1 is defined as a voltage of 8.5 volts minimum):

- Pulse Width, 40 nanoseconds minimum
- Rise Time, 10 nanoseconds maximum
- Fall Time, 200 nanoseconds maximum

(2) AGC Control Voltage - The video amplifier shall supply a voltage from +2 to +7.5 volts into a 50KΩ load.

2.6.3 Worst Case Performance Analysis

2.6.3.1 Amplifier Design

A schematic of the video amplifier is shown in Figure 2-25. The amplifier consists of two stages of gain. Each stage contains a monolithic amplifier (MC1733). The first stage (Z1) operates with a single ended input and differential output and has a typical voltage gain of 70. The second stage (Z2) has a differential input and a single ended output with a typical gain of 30.

Each stage has as a gain control, a junction field effect transistor which reduces its gain during the TPG period. The gain of the video amplifier is adjusted by a differential L-Pad (R_{12}, R_{14}, and R_{13}, R_{34}). The gain is adjusted during manufacture to compensate for variations in stage gains and threshold levels.

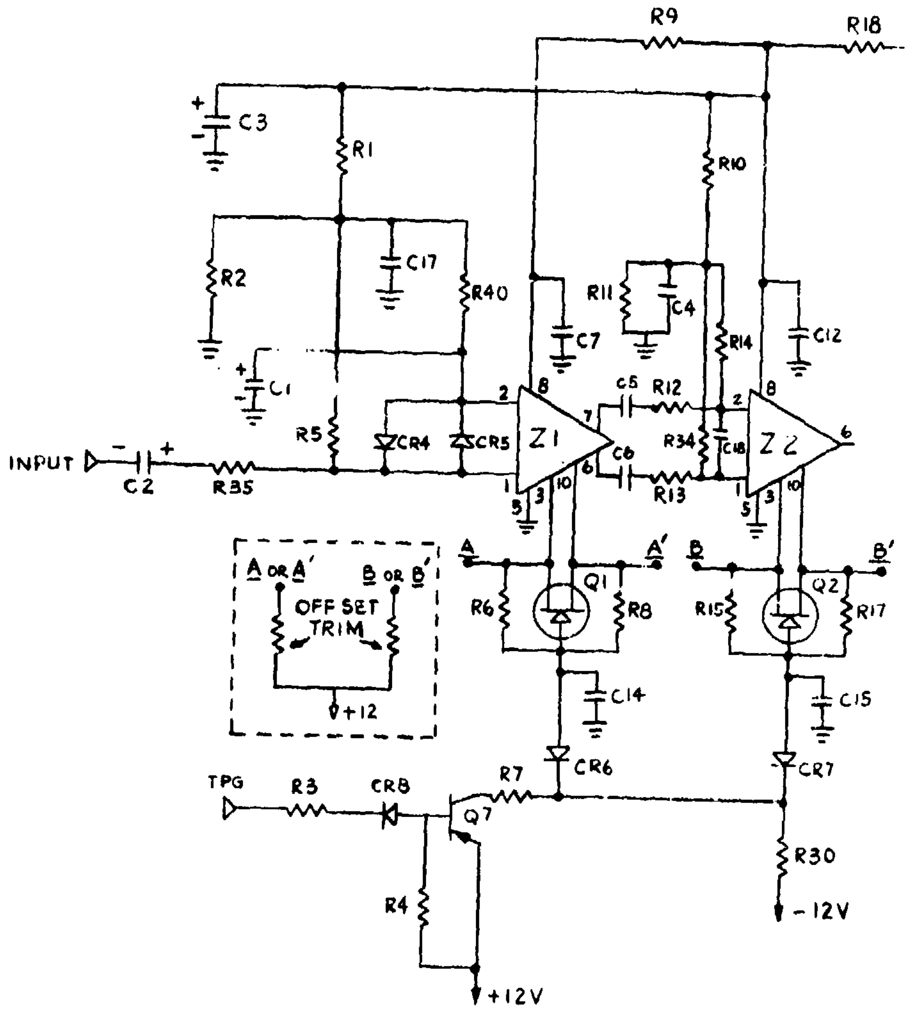


Figure 2-25. Amplifier and TPG Gate

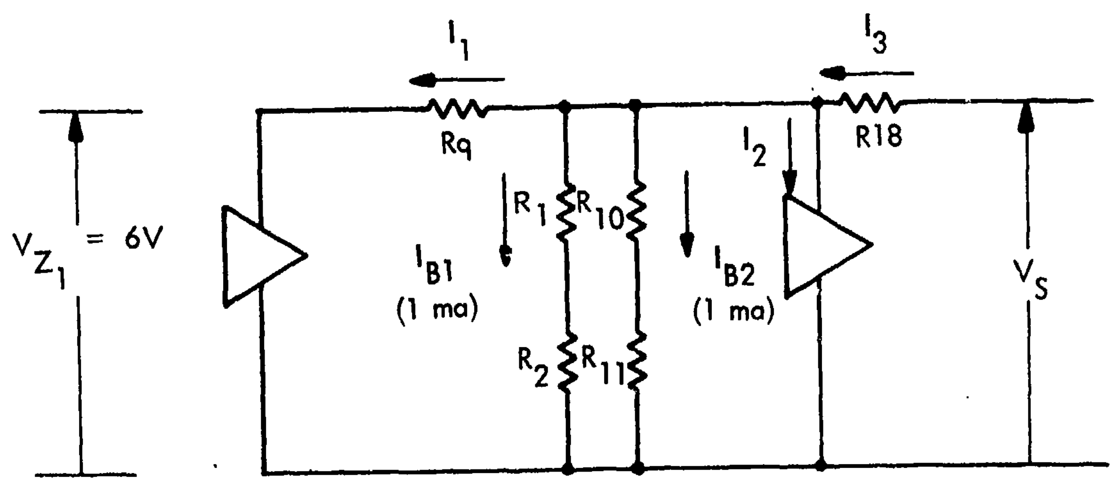
To reduce power consumption each video amplifier stage requires only one supply. A pair of resistor dividers is used to bias the amplifier inputs.

A pair of back to back diodes (CR4 and CR5) across the input stage of Z1 protects the amplifier from the large output swing available from the preamplifier which can theoretically reach 15 volts. A resistor (R35) prevents overload of the preamplifier when these diodes conduct. This resistor results in a 1 dB loss in gain at low signal levels. The TPG control transistors (Q_1 and Q_2) are driven from a switch Q7 whose input is the TPG gate. The TPG gate has a low source impedance of 250Ω maximum and is capable of supplying the full supply voltage through this source impedance. Two capacitors (C14 and C15) in conjunction with the resistors, R_6, R_8, R_{15}, R_{17} set the time programmed gain time response characteristic.

In order to insure that the video amplifier meets its requirements under the worst case conditions of input levels and parameter tolerances, a number of worst case analysis have been made. These include the video amplifier bias voltage conditions and the TPG turn on and turn off requirements.

2.6.3.1.1 <u>Amplifier Bias Calculations</u>

The first calculation is that of the amplifier bias and gain conditions. To compute the minimum supply voltage of Z_1 and Z_2, a minimum voltage of 6V was assumed to be required and then calculations were made under worst case conditions to see that this assumption was met.



The calculation of the minimum supply voltage required to provide a minimum of +6V to Z_1 requires the following assumptions:

V_{Z1} = 6V minimum

I_{B1} = 1 mA max

I_{B2} = 1 mA max

R_g = 105Ω max

R_{18} = 105Ω max

From the manufacturer's data sheet for the MC1733.

I_1 = 8 mA typical

Using the $I_{max}/I_{typical}$ ratio of 1.3 given in the data sheet at the operating voltage of ±6V yields, at the operating voltage of ±3V, a current I_1 computed as follows:

I_1 = 1.3 $I_{typical}$

= 1.3 x 8 mA

= 10.4 mA maximum

This current flows through R_9 and produces a voltage drop across R_9 of 1.1 volts. When added to V_{Z1} this voltage yields the following for V_{Z2}.

V_{Z2} = 6.0 + 1.1 = 7.1 volts

From the data sheet a typical current of 10 mA will be drawn by Z_2 under this voltage condition. The maximum can be computed in the same manner as for Z_1.

I_2 = 1.3 I_2 typical

= 1.3 x 10 mA

= 13 mA

Current I_3 can now be computed

$$I_3 = I_1 + I_{B1} + I_{B2} + I_2$$

$$= (10.4 + 1 + 1 + 13) \text{ mA}$$

$$= 25.4 \text{ mA}$$

This current is drawn through R_{18} and produces a voltage drop across R_{18} of 2.66 volts. When this drop is added to V_{Z2} the minimum required supply voltage can be calculated:

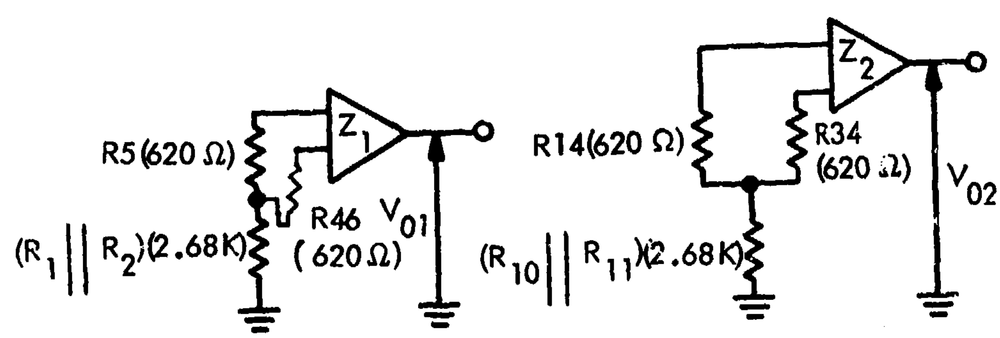
$$\text{Req'd } V_{s\ min} = V_{Z2} + 2.66 \text{ volts}$$

$$= 7.1 + 2.66$$

$$\approx 9.76 \text{ volts}$$

Since the minimum power supply voltage on the +12 volt rail will be 11.4 volts, the minimum V_{Z1} condition is met.

A second calculation is required to compute the output offset voltages due to the input bias current and voltages. To calculate these offsets under worse case conditions, refer to the following circuit diagram.



Output Offset Voltage Due to the Common Mode Voltage Caused by the Bias Current

Assuming a worst case CM_{Rej} of 40 dB or 100:1 and a bias current of 20 μA.

$$\Delta V_{o1} = \Delta V_{in} CM_{Rej}$$

$$\Delta V_{o1} \cong I_{bias}\left(R_1 \| R_2\right) CMR_{ej}$$

$$\Delta V_{o1} = 20 \times 10^{-6} \times 2.68 \times 10^{3} \times 10^{-2}$$

$$\Delta V_{o1} = 0.536 \times 10^{-3} \text{ volts}$$

and $$\Delta V_{o2} \cong \Delta V_{o1}$$

Output Offset Voltage Due to the Differential Input Voltage Caused by the Bias Current

Let ΔR = (R5 (max) - R40 (min))

$$\Delta V_{o1} = I_{bias} \times \Delta R \times G_{max}$$

$$= 20 \times 10^{-6} \times 102 \times 55$$

$$= 0.112 \text{ volts}$$

Let ΔR = (R14 (max) - R34 (min))

$$\Delta V_{o2} = I_{bias} \times \Delta R \times G_{max}$$

$$= 20 \times 10^{-6} \times 102 \times 55$$

$$= 0.112 \text{ volts}$$

Output Offset Voltage Due to the Input Bias Voltage

Since the bias network (R_1, R_2) for the input of Z_1 is not taken from the V_{cc} point of Z_1 there will result an offset voltage at the input to Z_1 equivalent to the drop in the decoupling resistor divided by the bias resistor ratio of $R_2/(R_1+R_2)$.

Assuming a maximum drain current of 15 mA for Z_1, the voltage drop across R_9 is 1.58V

$$\Delta V_{01} = \Delta V \times \frac{R_1}{R_1 + R_2} \times CM_{REJ}$$

Since $R_2 = R_1 \pm 5\%$

$$\Delta V_{01} = 1.58 \times 0.49 \times 10^{-2}$$

$$= 7.7 \times 10^{-3} \text{ volts}$$

An additional offset is due to the difference in bias resistors R_1 and R_2. If a 5 percent difference is assumed with a maximum of +12V on the bias resistors, this offset voltage will be

$$\Delta V_{01} = 5.0\% \times V \times CM_{Rej}$$

$$\Delta V_{01} = 0.05 \times 12 \times 10^{-2}$$

$$= 7.0 \times 10^{-3} \text{ volts}$$

For Z_2 only the difference in the bias resistors will cause an offset.

Assuming the same worst case conditions:

$$\Delta V_{02} \sim \Delta V_{01} \approx 7.0 \times 10^{-3} \text{ volts}$$

There is one additional source of output offset -- the input offset current. This can be checked as follows assuming a worst case offset current of 3 microamperes and the input impedance to be the average input resistance.

$$\Delta V_{01} = I_{offset} \times R_{AVE} \times G_1$$

$$= 3 \times 10^{-6} \times \frac{(510)}{(2)} \times 55$$

$$= 41 \times 10^{-3} \text{ volts}$$

$$\Delta V_{02} = \Delta V_{01}$$

As can be seen from the above analysis, none of the offset voltages are significant enough to limit the dynamic range of the MC1733 which is a minimum of 1 volt at $V_{Z_1} = 6$, and 2 volts at $V_{Z_2} = 8$ volts. The output sink current is 1 milliamperes at $V_{Z_1} = 6V$ and 1.5 milliamperes at $V_{Z_2} = 8$ volts.

2.6.3.1.2 Gain Calculations

The maximum allowable gain is that gain which will amplify the receiver noise exclusive of the APD diode noise to the point where it will contribute < 1 pps to the threshold crossing rate (TCR). The threshold to noise ratio (TNR) for a 1 pps TCR can be calculated from equation on page 2-114. The calculated TNR is 5.56. If a threshold voltage of 0.8 volts is assumed, the maximum video amplifier output noise should be 143 millivolts.

The total system noise exclusive of the APD diode is

$$v = \sqrt{v_{VA}^2 + v_{PA}^2 + v_{RL}^2}$$

where v_{VA}, v_{PA} and v_{RL} are obtained from Table 3-6.

$$v = \sqrt{19.3^2 + 58^2 + 36^2} \text{ microvolts}$$

$$= 71 \times 10^{-6} \text{ volts}$$

The maximum allowable gain is therefore

$$G_{max} = \frac{143 \times 10^{-3}}{71 \times 10^{-6}} = 2000$$

The minimum required video amplifier gain is that gain which will allow the minimum received signal level to exceed the threshold with a probability of detection of 99% when the SNR = 6.98. Since the minimum SNR occurs at the high temperature (see Table 3-6), the minimum received signal voltage must be calculated at this temperature.

Table 3-6 shows that a signal of 2.84 mv yields a SNR of 10, therefore a signal level that would yield a SNR of 6.98 is

$$V_{S_{pk}} = 2.84 \times \frac{6.98}{10.00} = 2.0 \text{ mv}$$

Assuming a threshold of 0.8V, the minimum allowable gain is

$$G_{(min)} = \frac{0.8V}{2 \times 10^{-3} V} = 400$$

The actual worst case minimum gain can be calculated using the following assumptions. The minimum voltage on Z_1 is 6 volts as assumed previously in the bias calculations. The worst case minimum voltage on Z_2 will be 8 volts which in effect assumes the 30 milliampere maximum allowable current drain at the minimum supply voltage. In order to adjust the typical gain specifications of the MC1733 to the worst case operating temperature and voltage, the following gain factors have been taken from the manufacturers data sheet.

	Z_1	Z_2
Minimum Gain at 25°C V_S = 12V	45	90
Gain reduction factor at +70°C	0.95	0.95
Gain reduction factor at V_{Z1} = 6V	0.75	
V_{Z2} = 8V		0.88
Gain reduction factor at R_{adj} = 35Ω	0.8	0.8
Gain of Z_1 at +70°C, 6V, R_{adj} = 35Ω	25.6	
Gain of Z_2 at +70°C, 8V, R_{adj} = 35Ω		60
Minimum overall gain =	25.6 x 60 = 1536	

Since the minimum overall gain of 1536 is greater than the minimum allowable gain of 400, the low gain condition can be met. The worst case maximum gain is difficult to calculate. However, it will never exceed the maximum gain product of Z_1 and Z_2 without reduction factors. This worst case gain is

$$G_{max} = 55 \times 110 = 6050$$

Since this gain exceeds the maximum allowable, the resistive pad R_{12}, R_{14}, and R_{13}, R_{34} will be trimmed to reduce the gain below 2000.

2.6.3.1.3 Time Programmed Gain

The time programmed gain control circuit increases the gain of the video amplifier as a function of time. For this circuit several calculations are required. These calculations are: the maximum attenuation during the TPG gate, the conditions to insure that Q_1 and Q_2 are fully turned on and off, and the time profile of the gain recovery of the video amplifier. Refer to Figure 2-28.

The maximum amount of attenuation inserted during the TPG gate is essentially the ratio of the gain 2 to gain 3 condition specified on the data sheet with gain 2 adjusted for the resistance of the FET (Q_1 or Q_2) across the R_{adj} terminals. Under the worst case condition of 35 ohms across the R_{adj} terminals, the gain reduction will be 6:1 in each amplifier or 36:1 overall. This is a 31 dB reduction in voltage gain. The measured gain reduction on the breadboard is 33 dB.

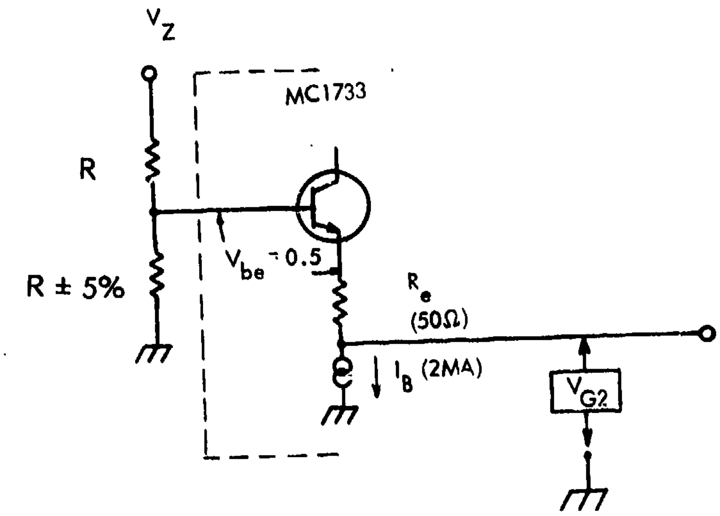
In order to insure that the full TPG attenuation is obtained, it must be shown that Q_1 and Q_2 are fully off. Likewise to insure that the full video gain is realized, it must be shown that Q_1 and Q_2 are fully on. To show the above, it is first necessary to compute the maximum and minimum dc voltages on the gain control terminals of the video amplifiers Z_1 and Z_2. These dc voltages will be referred to in the following analysis as V_{G2} (max) and V_{G2} (min).

The worst case condition for Q_1 or Q_2 turn on is when V_{G2} is at its maximum level. To compute this voltage the following assumptions have been made. The maximum voltage (VZ) on the bias resistor network (R_1, R_2) and (R_{10}, R_{11}) is assumed to be 9.0 volts corresponding to a current drain of 15 mA for the Video Amplifier. The minimum V_{be} of the input transistors of the MC1733 is 0.5 volts and the matching of the resistors in the bias network is 5 percent. Referring to the following circuit it can be seen that:

$$V_{G2}(\max) = \left[\frac{1.05}{2.05}\ V_Z\right] - V_{be} - I_B R_E \qquad (1)$$

$$V_{G2}(\max) = \left[4.61\right] - 0.5 - 0.1$$

$$V_{G2}(\max) = 4.01 \text{ volts}$$



To determine the minimum voltage $V_{ez}(\min)$ at the gain terminals, a bias voltage (VZ) of 8.5V and a maximum V_{be} of 0.8 volts has been assumed.

$$V_{G2}(\min) = \left[\frac{0.95}{1.95}\ V_Z\right] - V_{be} - I_B R_E$$

$$= 4.14 - 0.8 - 0.1$$

$$= 3.24 \text{ volts.}$$

In order to insure Q_1 and Q_2 turn on, diodes CR6 and CR7 must be reverse biased. Under this condition $V_{GS} = 0$ and "v_{ds} on" of Q_1 and Q_2 are at their minimum value.

To reverse bias CR6 and CR7, switch Q_7 is turned on by a logic zero on the TPG gate input. The base current of Q_7 is then approximately

$$I_b(Q_7) = \frac{+12V - V_{be} - V_E\ (CR8)}{R_3}$$

$$= \frac{+12 - 0.7 - 0.7}{10^4}$$

$$= 1\ \text{ma.}$$

This current is sufficient to saturate Q_7. With Q_7 saturated, the divider formed by R_7, R_{40} and V_{sat} of Q7 places the cathode of CR6 - CR7 at

$$V_C = \frac{\left[+12 - (-12V) - V_{sat}\right]}{R_7 + R_{30}} R_{30} - 12V$$

$$V_C = 6.7\ \text{volts}$$

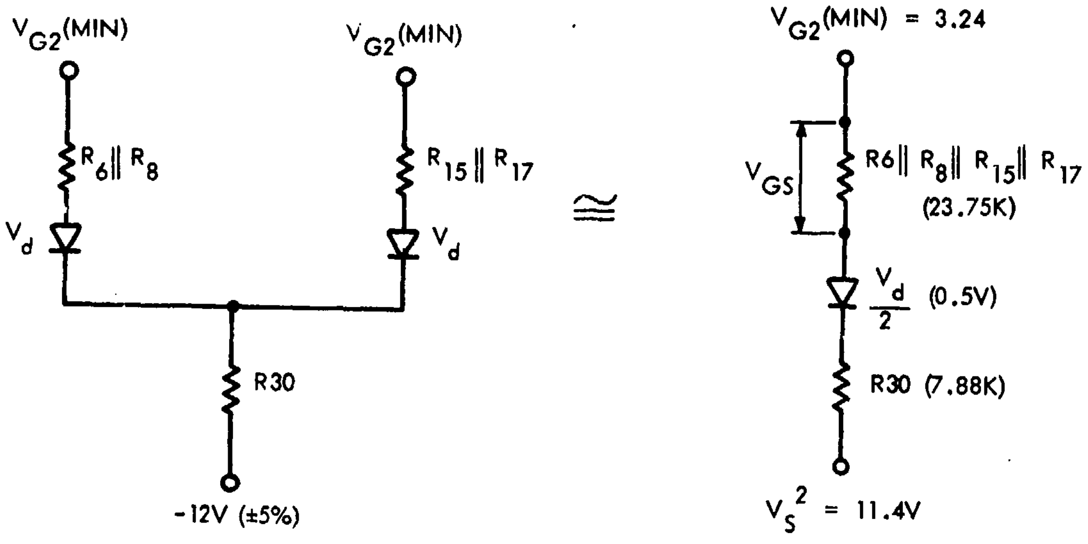
The maximum anode voltage of CR6 and CR7 is equal to V_{G2} (MAX) when CR6 and CR7 are reverse biased. V_{G2} (MAX) was previously calculated to be 4.01 volts, thus $V_R = V_C - V_A$.

$$V_R = 6.7 - 4.0 = 2.7\ \text{volts}$$

and CR6 and CR7 are reverse biased.

In order to turn Q_1 and Q_2 off, the gate to source voltage of Q_1 and Q_2 must be less than their specified pinchoff voltages. The specified pinchoff voltage of Q_1 and Q_2 is -10V.

V_{GS} (OFF) can be computed when Q_7 is switched off from the following equivalent circuit using the previously computed value of V_{G2} (MIN). It is assumed $\Delta V_{ds} = 0$, I_c (Q7) = 0, and R_6 through R_{17} are at their minimum values.



$$MIN_{V_{GS}}(OFF) = \frac{V_{G2}(MIN) - (V_S) - \frac{V_d}{2}}{(R_6 \parallel R_8 \parallel R_{15} \parallel R_{17}) + R_{30}} (R_6 \parallel R_8 \parallel R_{15} \parallel R_{17})$$

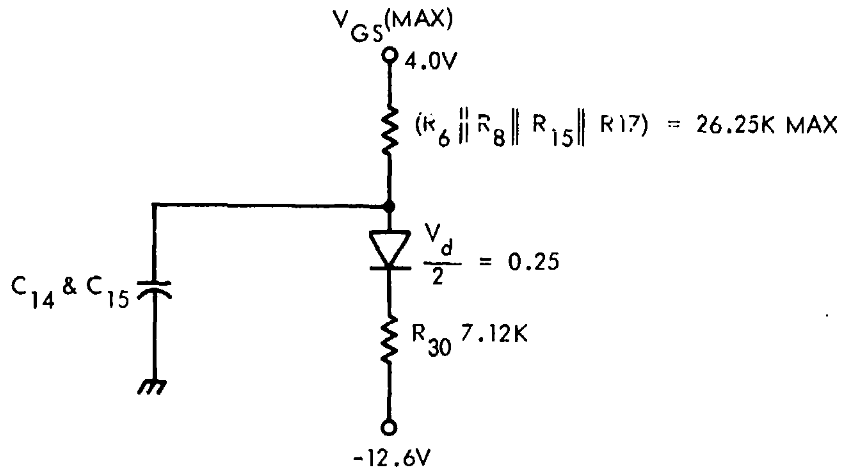
$$= \frac{3.24 - (-11.4) - 0.5}{23.75K + 7.88K} (23.75K)$$

$$MIN_{V_{GS}}(OFF) = -10.6 \text{ V}$$

The time profile of the TPG circuit is determined by the time constant of $R_6 \parallel R8$ and C14, $R_{15} \parallel R_{17}$ and C15, the actual pinchoff voltage of Q_1 and Q_2; and the applied pinchoff voltage.

This discharge is given by $V_1 + (V_2 - V_1)(1 - e^{-t/RC})$, where V_1 is the initial charge voltage on C14 or C15 and V_2 is the final charge.

The most negative initial charge on C14 or C15 which yields the longest discharge time can be computed from the following circuit



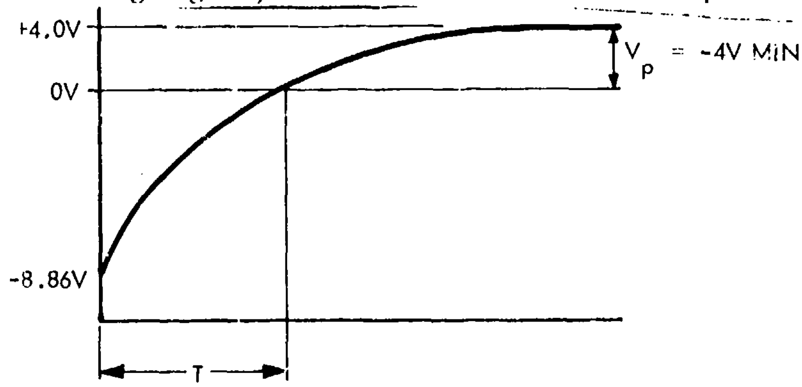
$$V_{C14} = \left[\frac{V_{GS} - (-12.6) - 0.25}{(R_6 \parallel R_8 \parallel R_{15} \parallel R_{17}) + R_{30}}\right](R_{30}) - 12.35$$

$$= \left[\frac{4.0 - (-12.6) - 0.25}{33.37 \times 10^3}\right] 7.12 \times 10^3 - 12.35$$

$$= -8.86 \text{ volts}$$

Since C_{15} is larger than C_{14} it controls the total discharge time.

Refering to following Figure, the max TPG time can be computed.



$$V_{GS}(MIN) - V_p(MIN) = 0$$

$$0 = -8.86 + (12.86)\left(1 - e^{-\frac{T}{4.33 \times 10^{-6}}}\right) \qquad \tau = 26.25K \times 165\ pf$$

$$\tau = 4.33 \times 10^{-6}$$

$$T = -4.33 \times 10^{-6} \ln \left[1 - \frac{8.86}{12.86}\right]$$

$$T = 5 \times 10^{-6} \text{ seconds}$$

2.6.3.1.4 Pulse Stretching

Pulse stretching in the video amplifier must be determined empirically due to the non-linear operation of the devices. For the low level case, the differential over-drive recovery time is given for the MC1733. For a 200 mV differential input voltage, the recovery time is specified as 60 nanoseconds. The coupling networks in the video amplifier have been selected to minimize the recovery time and a pair of back to back diodes in the input stage Z_1 will prevent severe overdrive for the single ended input. Measurements have been made on the breadboard and the results are shown in the breadboard test data section. For signal inputs of less than 1 volt the pulse stretching at the threshold output is less than 250 nanoseconds.

2.6.3.2 Threshold Circuit

The output of the video amplifier drives a threshold circuit composed of an NPN-PNP common emitter pair. This circuit is shown in Figure 2-29.

2.6.3.2.1 Threshold Temperature Variations

Threshold level is set by the V_{be} of Q_3 which varies by 2.1 millivolts/°C and has an absolute value between 0.5 volts and 0.7 volts. The worst case variation occurs at low temperature when the absolute threshold is at 0.5 volts.

$$\%\text{ change in } V_{be} = \frac{(46°C + 25°C)\ 2.1 \times 10^{-3}\ mv/°C}{0.5} \times 100$$

$$= 30\%\text{ increase}$$

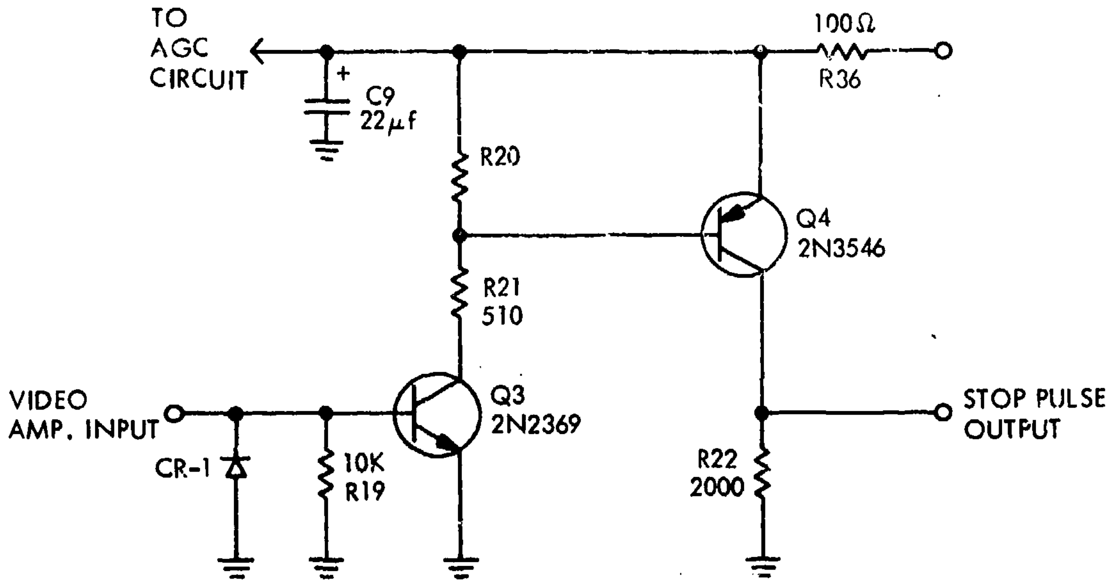


Figure 2-26. (C) Threshold Circuit

At the high temperature extremes the % change in V_{be} will be

$$\% \text{ change in } V_{be} = \frac{(70°C - 25°C)2.1 \times 10^{-3} \text{ mv/°C}}{0.5} \times 100$$

$$= 21\% \text{ decrease}$$

the overall variation will then be 51%.

If the video amplifier gain were fixed this total change would be reflected in a corresponding change in the APD diode gain. The video amplifier gain, however, is a function of the FET (Q_1, Q_2) ON resistance which varies with temperature (+ TC = 0.7%/°C) in such a manner as to partially reduce this temperature dependence. Changes in video amplifier gain or threshold levels will be reflected in corresponding changes in APD gain due to the AGC loop.

Measurements on the breadboard system oven temperature show a -2, + 1 dB change in the receiver threshold level. The effect on system sensitivity due to small changes in the APD gain M can be neglected since both the signal and noise are reduced or increased by the same amount. This is shown in the following equation for the signal-to-noise ratio:

$$\mathrm{SNR} = \frac{i_s M}{\sqrt{2eB\left[M^2 F \left(I_{db} + SP_b\right) + I_{ds}\right] + i_{ae}^2}}$$

for large M this reduces to

$$\mathrm{SNR} = \frac{i_s M}{\sqrt{2eBM^2 F \left(I_{db} + SP_b\right)}} = \frac{i_s}{\sqrt{2eBF \left(I_{db} + SP_b\right)}}$$

Thus the SNR is independent of gain M as a first-order effect. The above relations hold for the case where the minimum gain is sufficient to raise the diode noise above all other noise sources.

In the AN/GVS-5 system, the above conditions will be met by assuring that the threshold is always above the receiver noise exclusive of the APD noise. If this is true the gain of the APD will be increased by the AGC loop until its noise crosses the threshold.

2.6.3.2.2 Threshold Switching Times

The threshold switching time is determined by circuit device and stray capacitance loading as well as the delay, rise, storage, and fall times of the active devices. Because these parameters vary as a function of operating current and voltage levels, a worst-case analysis is not practical. In order to insure sufficiently fast rise and fall times, the active devices used are high speed switches with low capacitance. In addition to low device capacitance the collector impedances have been kept low to provide fast discharge paths. The collector impedance of Q_3 is 740 ohms and Q_4 is 2.2 Kohms. The worst case rise and fall times for the threshold occurs at low levels and measurements on the breadboard have indicated a 10 nanosecond rise and 100 nanosecond fall time for signals levels that produce a 40 nanosecond wide stop pulse.

2.6.3.3 Avalanche Photodiode Automatic Gain Control

The Avalanche Photodiode Automatic Gain Control Circuit is composed of a one shot, a peak detector, and a buffer amplifier. A schematic of the APD AGC circuit is shown in Figure 2-27.

2.6.3.3.1 Worst Case Analysis of the One Shot

Noise pulses exceeding the threshold trigger a 70 microsecond one shot consisting of Q_5 and Q_6. In order to conserve standby power this one shot configuration has both transistors normally biased off. The trigger pulse turns on both stages and the charge current for the timing capacitor is through the saturated collector ($V_{CE}SAT$) of Q_6, the 3.9K ohms resistor, (R25) the 0.005 capacitor, (C10) and through the base to emitter diode of Q_5. The discharge path for the capacitor is through the 10K base resistor of Q_5 and the 10K collector resistor of Q_6. An analysis of the pulse width variations due to temperature can be made using the following equivalent circuit.

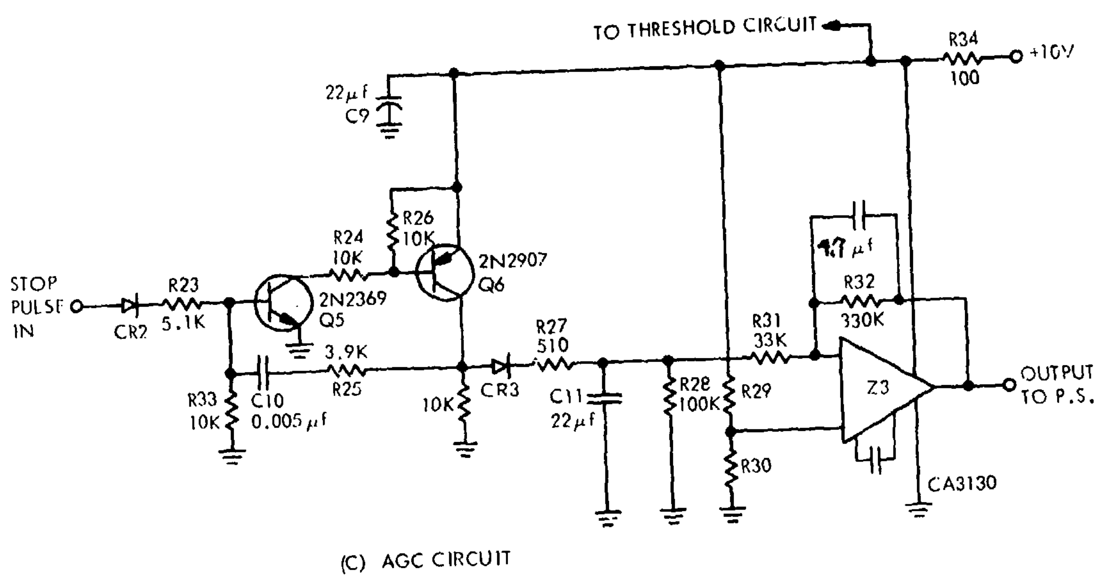
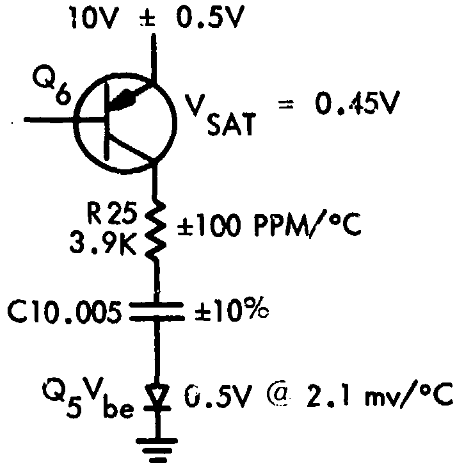


Figure 2-27. Avalanche Photodiode AGC Circuit



For a temperature variation from -50°C to +70°C

$$\Delta R = 1.2\% \text{ and } \Delta V_{be} = \pm 0.125 \text{ volts}$$

The time constant then will change by ±1.2% for the resistor and ±10% for the capacitor for a total of ±11.2% while the charging voltage will change by +6.25%. The total variations in pulse width should be less than ±17.5%. To compensate for this pulse variation the TCR will shift by ±17.5%. Breadboard tests indicate a change in pulse width of 10% over the full temperature range.

2.6.3.3.2 Peak Detector

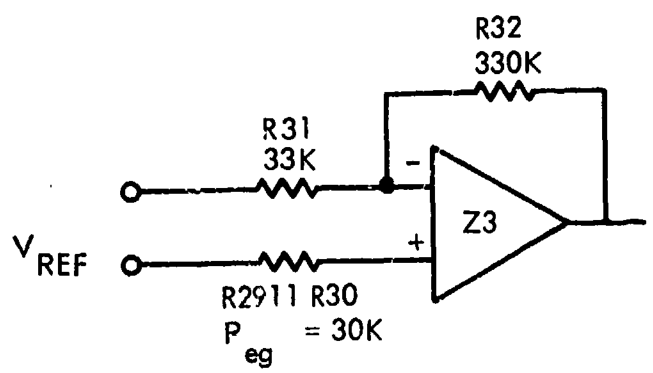
The output of the APD one shot is converted to a DC voltage by a peak detector consisting of R27, CR_3, C11, and R28.

The tolerance on the charge time is controlled by the charging voltage and the charging time constant. The equivalent charging voltage varies by the change in the power supply voltage, the change in V_{sat} of Q_6 and the change in the forward voltage drop of CR-2. The power supply voltage will change by ±5% or ±0.5V. The V_{sat} of Q_6 is independent of temperature but will vary from unit to unit by ±0.3V. The V_{be} of the diode varies by 2.1 mv/°C (±0.25V) and by as much as ±0.25V from unit to unit. The total variation can be as high as ±1.3V. This is equivalent to a ±10% change in the nominal +10V charging voltage. The variation in the charging time constant is due to a variation in the charging resistor R_{27} which is 1.4% maximum and to the storage capacitor which has a ±5% initial tolerance and a variation of ±2% due to temperature. Since the nominal charging time constant is long (11 msec) with respect to the one shot pulse width (70 μsec) the variation in the charging T.C. will affect the output voltage.

The discharge time constant tolerance is the same as the charging time constant or ±7%. The total worst case variation is the sum of the above tolerances or ±26.8%. Adding in the tolerance of the one shot pulse width of ±17.5% yields a total variation of ±44.3% in the TCR. This corresponds to a +3, -2% change in the threshold with a nominal TCR of 600 pps.

2.6.3.3.3 Buffer Amplifier

The output of the peak detector is amplified and buffered in a DC amplifier Z3. The equivalent circuit of the DC amplifier is shown below. For the purpose of these calculations the non-inverting input bias network has been converted to a Thevenin equivalent voltage source.



Note

$$R_{31} \parallel R_{32} = 30K$$

$$R_{38} \parallel R_{39} = 30K = R_{eg}$$

The assumed worst case values of Bias and Offset for the MC1741 are:

I_b Bias Current	11 na	-55°C to +125°C
I_o Offset Current	3 pa	
V_o Offset Voltage	15 mv	

Note

$$G \quad \frac{330K}{33K} = 10$$

$$\Delta V_o \Big|_{I_b} = I_b (\Delta R) \times G \qquad \Delta R \quad 1\% \text{ Requivalent} = 300$$

$$= 11 \times 10^{-9} (300)\ 10$$

$$= 33\ \mu v$$

$$\Delta V_o \Big|_{I_o} = I_o \times (\text{Reqn.}) \times G$$

$$= 3 \times 10^{-9} \times 30 \times 10^{3} \times 10$$

$$= 0.9 \text{ mv}$$

$$\Delta V_o \Big|_{V_o} = V_o (1 + G)$$

$$= 15 \text{ mv } (11)$$

$$= 165 \text{ mv}$$

The total output offset voltage then is 166 mv.

A 166 mv shift in the output voltage corresponds to a change in TCR of 5%. Adding this tolerance to the 44.3% tolerance due to the one shot pulse width and peak detector yields a 49.3% change in the TCR. Since the initial FAR is 600 the maximum will be 900 pps and the minimum will be 300 pps.

2.6.4 Bench Test Data

2.6.4.1 Test Data

The operation of the video amplifier was verified by measurements made on a breadboard using discrete components. The input was simulated by a video pulse generator and measurements were made to verify various operating characteristics.

The video amplifier sensitivity was 1.4 millivolts at room temperature using a 10 nanosecond pulse. The video amplifier delay, measured between the 50% point on the input pulse and the 8 volt level on the output stop pulse was measured to be 28 nanoseconds at the minimum signal level and 15 nanoseconds when severely overdriven.

With two signals of equal amplitude spaced 670 nanoseconds apart, two distinct stop pulses were obtained at an input of 1V peak. No tests were made with two signals of different amplitudes or to the 15 Volt level that the preamplifier is capable of putting out. A spacing of 330 nanoseconds (50 meters) was measured for two signals of equal amplitude at 100 mV.

The TPG attenuation was measured as a function of time. The maximum attenuation at close ranges was 33 dB. A curve of TPG attenuation versus range (100 meters = 67 nanoseconds) is shown in Figure 2-28.

The AGC voltage as a function of the TCR is shown in Figure 2-29. This curve shows that the full range of the AGC voltage can be obtained with a variation of only 150 pps in the TCR.

2.6.4.2 Temperature Tests

The sensitivity of the video amplifier was measured by determining the change in signal level required to produce a 40 nanosecond wide stop pulse as a function of temperature. These tests indicate a change in sensitivity of 2 dB for a temperature variation from -50°C to +70°C. The pulse width of the APD AGC one shot was measured over the operating temperature range and was 75 ± 5 microseconds.

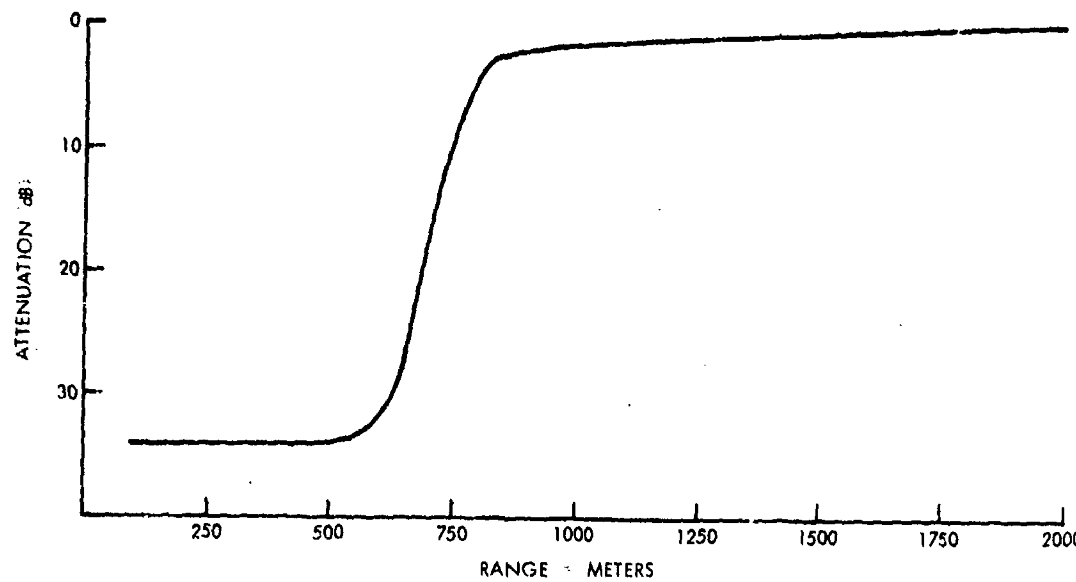


Figure 2-28. TPG Attenuation

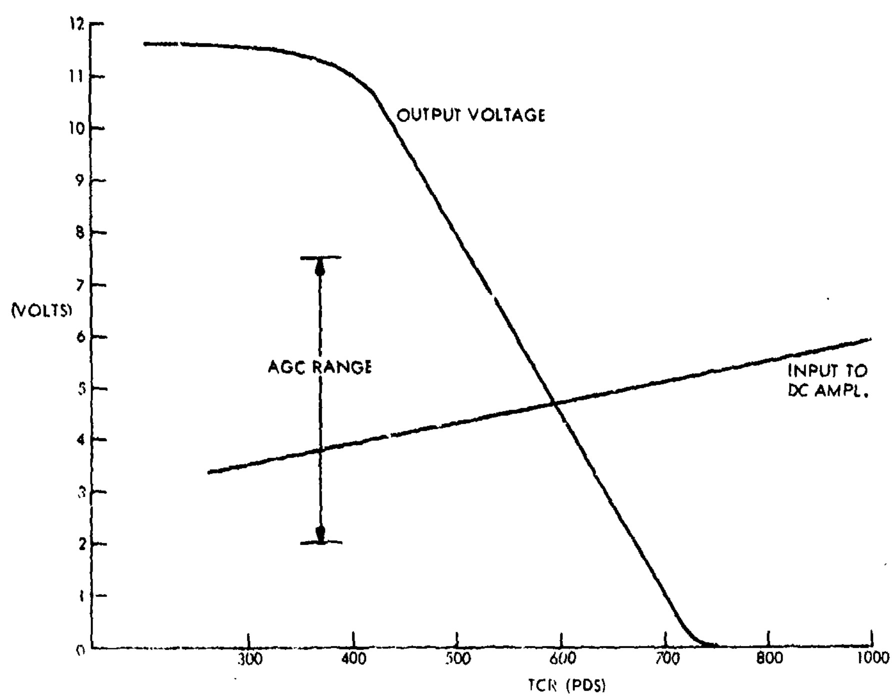


Figure 2-29. AGC Output Voltage

2.7 POWER SUPPLY MODULE

2.7.1 Power Supply Packaging

The power supply is configured as an assembly of printed circuit boards containing discrete parts. Its physical configuration is shown in RCA 2378714. It is mounted to four bosses located in the side of the Optical Assembly. Electrical interfacing is by flexprint soldered to pins on the Power Supply for the low voltage section. For the high voltage connections, interfacing will be through hard wired connections. The connections will be safety protected by the application of a thick coating of a urethane based elastomer. Conformal coating will be applied to assure protection against moisture or surface contamination. The Power Supply Envelope Drawing is given in Appendix 9.10.

2.7.2 Electrical Design

2.7.2.1 Description of Operation

Laser rangefinder voltages are generated by the Power Supply Module. These voltages include the pulse forming network capacitor voltage, avalanche detector voltage, and system low voltages.

The pulse forming network capacitor charging converter is activated by application of the specified battery voltage on one line upon actuation of the FIRE pushbutton.

The avalanche detector voltage, and system low voltages are activated by application of the specified battery voltage on one line independent of the capacitor charging converter upon actuation of the FIRE or MIN RANGE SET pushbuttons.

An undervoltage cut-out circuit is provided in the Power Supply Module to inhibit operation whenever the battery input voltage drops below 19 ± 1 volts.

2.7.2.1.1 System Low Voltages

Upon application of battery input voltage to the low voltage section of the Power Supply Module, the undervoltage cut-out circuit (comprising Q9, Q10, CR9, CR10, VR2 and associated components) monitors the input battery voltage level.

Q9 and Q10 form a flip-flop that enables (Q10 ON) or inhibits (Q10 OFF) the 12.8 volt regulator depending on the level of the battery input voltage. The nominal voltage at which the undervoltage cut-out circuit operates is 19.0 VDC.

Resistor divider R21 and R22 and VR2 establish the base voltage level of Q10 such that at input battery voltage levels greater than 19.0 volts Q10 is forward biased ON. The voltage at the collector of Q10 causes CR10 to conduct, establishing a high positive potential at R20 which biases CR9 off. This assures that Q9 cannot turn on.

As the battery voltage drops, the voltage at the junction of R21 and R22 and therefore the base of Q10 drops at a slower rate than the emitter of Q10. When the battery voltage reaches 19 volts, the base-to-emitter voltage of Q10 is sufficient to keep Q10 on.

When Q10 turns off, the current through CR10 and R20 ceases and CR9 is no longer reverse biased. Q9 now turns on and essentially connects R19 in parallel with R21 thereby increasing the voltage on the base of Q10 through VR2 assuring that Q10 remains off. This circuit can only be reset (Q10 ON) by removing the battery input voltage and reapplying with a level greater than 19 ± 1 volts.

Capacitor C9 assures that upon turn-on Q9 cannot conduct and cause the base voltage of Q10 to instantaneously rise high enough to keep Q10 off.

When Q10 is on, base current is provided to turn on Q13 which in turn turns on Q12, the switching-mode regulator pass transistor. The voltage across C13 rises until Q11 turns on which diverts base current from Q13. Q13 turns off and causes Q12 to turn off thereby removing battery voltage to L1. C13 discharges until Q11 turns off turning on Q13 and Q12 and the cycle repeats developing the 12.8 VDC for the low voltage power supply inverter circuit.

The inverter formed by Q14, Q15, T3 and associated components switches at 20 kHz and generates the low voltages in T3 which are rectified, filtered and fed to the outputs of the power supply. The 12 VDC output is taken from the 12.8 VDC pre-regulator through CR13 and filter L3 and C17.

The low voltages generated are:

+12 VDC ± 5%
-12 VDC ± 5%
+ 4 VDC ± 10%

2.7.2.1.2 Avalanche Detector Voltage

Differential amplifier Q17 and Q18 compares the DETECTOR SUPPLY CONTROL SIGNAL (AGC voltage) with a portion of the output voltage developed across R34 and controls the operation of Q19.

Q19 supplies base current to Q21 which establishes the voltage level at the primary center-tap of T4. Q14 and Q15 form an inverter which generates a square-wave of voltage in the primary of T4. The amplitude of this square-wave is determined by the conduction level of Q21 which is controlled by the AGC voltage input level.

The secondary of T4 is connected to bridge rectifier CR25-CR28, and develops the avalanche detector voltage.

The avalanche detector voltage follows the AGC input voltage between the limits shown below:

AGC Voltage	Avalanche Detector Voltage
2.0 VDC	150 VDC ± 5%
7.5 VDC	550 VDC ± 5%

The avalanche detector voltage level is established near the diode avalanche point during the one-second capacitor charging interval.

Upon generation of the FULL CHARGE signal Q20 turns on and causes Q21 to turn off thereby stopping current flow through the primary of T4. At the same time Q22 is turned on which removes R50 from the divider placed across the detector supply outputs. This causes an instantaneous 3.5% reduction in avalanche detector voltage.

This method establishes an operating voltage level prior to lasing which assures high sensitivity with low probability of false alarm.

2.7.2.1.3 Capacitor Charging Converter

The capacitor charging converter charges the pulse forming network capacitor (26.4 microfarad) at the rate of 8 joules in one second. The voltage level is adjustable between 500 and 800 volts.

Differential amplifier Q1 and Q2 compares a portion of the output voltage developed at the junction of R7 and R4 to a fixed reference voltage (VR1) and controls the operation of Q4.

While the PFN capacitor is charging, Q4 is off and therefore Q5 is also off. One winding of T3 is supplying base current pulses to Q6 which conducts through the primary of T2 and T1. T1 is a current feedback transformer and the base current to Q6 is an exact replica of the collector current. While Q6 is conducting the secondary voltage of T2 reverse biases CR4 and no current is transferred to the load. Q6 continues to conduct until T1 saturates at which time it turns off. The voltage induced in the secondary of T2 reverses and CR4 conducts into the pulse forming network capacitor.

As output current returns through R14 it causes Q7 to turn on thereby preventing Q6 from turning on again until all of the energy stored in T2 is transferred to the PFN capacitor, at which time Q6 again conducts and the cycle repeats at the 20 kHz rate until the capacitor reaches full charge.

The full charge voltage level is set by R5. When the capacitor voltage reaches the preset level, Q2 conducts. This turns on Q3 which turns on Q4 and Q5.

When Q5 conducts, base drive to Q6 is diverted and Q6 turns off, and therefore stops the charging cycle.

Once the capacitor has charged the level preset by R5 it cannot recharge unless power is removed from the supply and reapplied. When Q3 and Q4 conduct, they cause Q4 to develop the FULL CHARGE SIGNAL across R9.

2.7.2.2 Input-Output Specifications

2.7.2.2.1 Inputs

The Power Supply Module accepts the following inputs:

(1) Primary Input Voltage - The primary input voltage is provided by a nominal 24 VDC 150 milliampere-hour Nicad battery. The input voltage limits are 20 - 30 VDC.

(2) Secondary Input Voltage - The secondary input voltage is 20 to 40 VDC. (Limited in the Remote Power Cable Connector Box to < 30 VDC.)

(3) Detector Supply Control Signal (AGC Voltage) - A 2.0 - 7.5 VDC level for controlling the detector voltage output level.

2.7.2.2.2 Outputs

The Power Supply Module provides the following outputs:

(1) Capacitor Charging Converter - The power supply charges the pulse forming network capacitor (26.4 microfarads) to 8 joules in one second. The maximum duty cycle is six chargings per minute for two minutes followed by one charging per two minutes for the next eight minutes. This cycle may be repeated indefinitely. The charge voltage level is adjustable between 500 VDC to 800 VDC and subsequent recharges are within 2.5% of the adjusted level.

(2) Avalanche Detector Voltage - The output voltage level is controlled by the AGC voltage input. With a 2 VDC AGC voltage the detector voltage output is 150 VDC. With a 7.5 VDC AGC voltage the detector voltage output is 550 VDC. Output to input linearity is ± 10%. Ripple voltage and spikes are less than 1 volt peak-to-peak.

(3) Low Voltages - The Power Supply Module generates the low voltages shown below:

(a) +12 VDC ± 5% at 65 milliampere
(b) -12 VDC ± 5% at 10 milliampere
(c) +4 VDC ± 10% at 75 milliampere

Ripple and spikes on the +12 and -12 volt supplies are less than 100 millivolts peak-to-peak.

(4) Full Charge Signal - A logic 1 level concident with ataining a full charge condition. A logic 1 level is defined as a voltage greater than 9.0 VDC and a logic 0 as less than 0.5 volt.

2.7.2.3 Schematic Diagram

The Power Supply Module schematic diagram is shown in Figure 2-30. The breadboard Power Supply schematic is shown in Figure 2-31.

2.7.3 Worst Case Performance

The Breadboard Power Supply Module component electrical stress tabulation is shown in Table 2-9.

2.7.4 Breadboard Test Data

2.7.4.1 Bench

Power Supply Module capacitor charging converter bench test data is shown in Table 2-10. The low voltage and detector voltage power supply test data is shown in Table 2-11.

2.7.4.2 Temperature

Temperature effects on the Power Supply Module are shown in Tables 2-12 through 2-13.

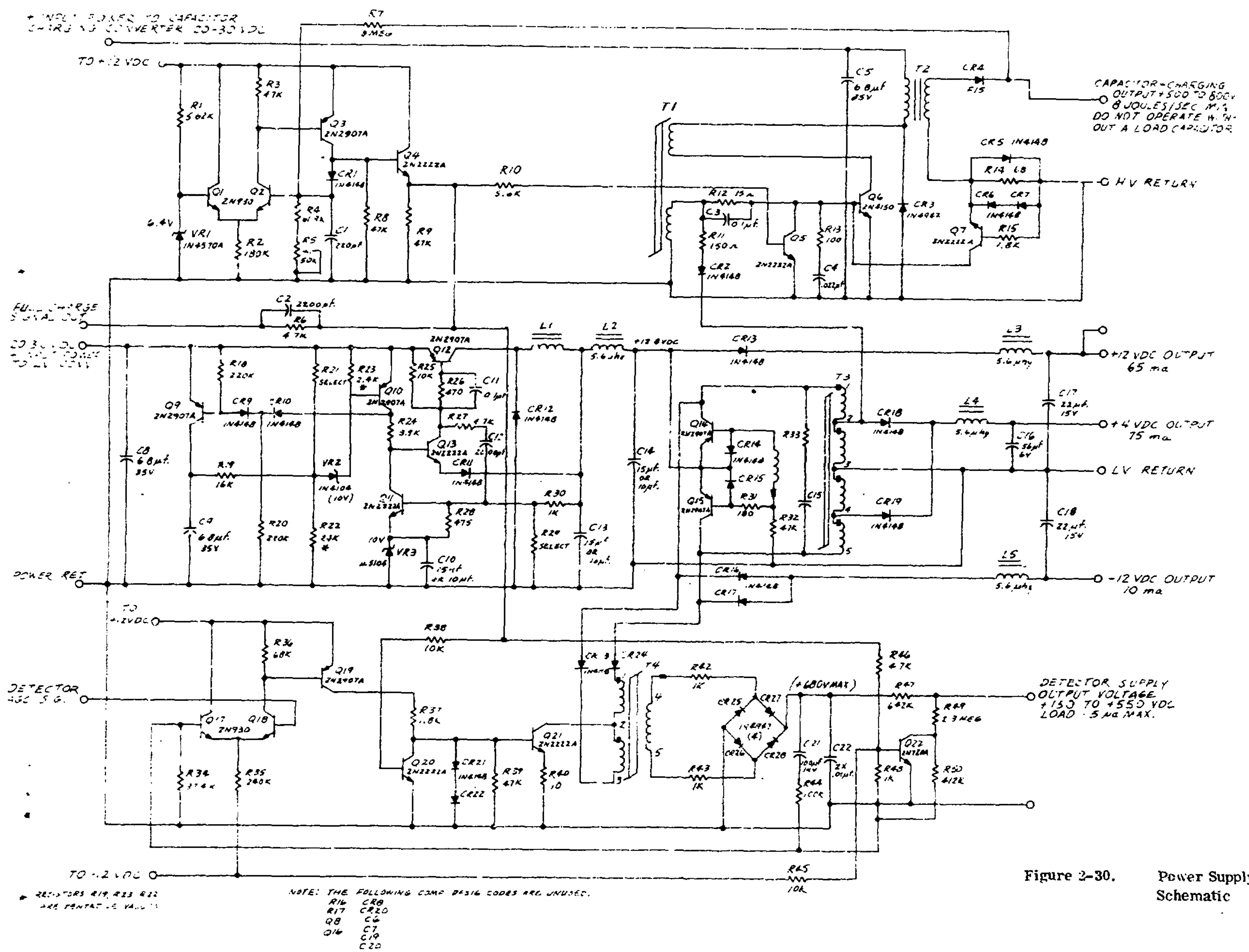


Figure 2-30. Power Supply Module Schematic

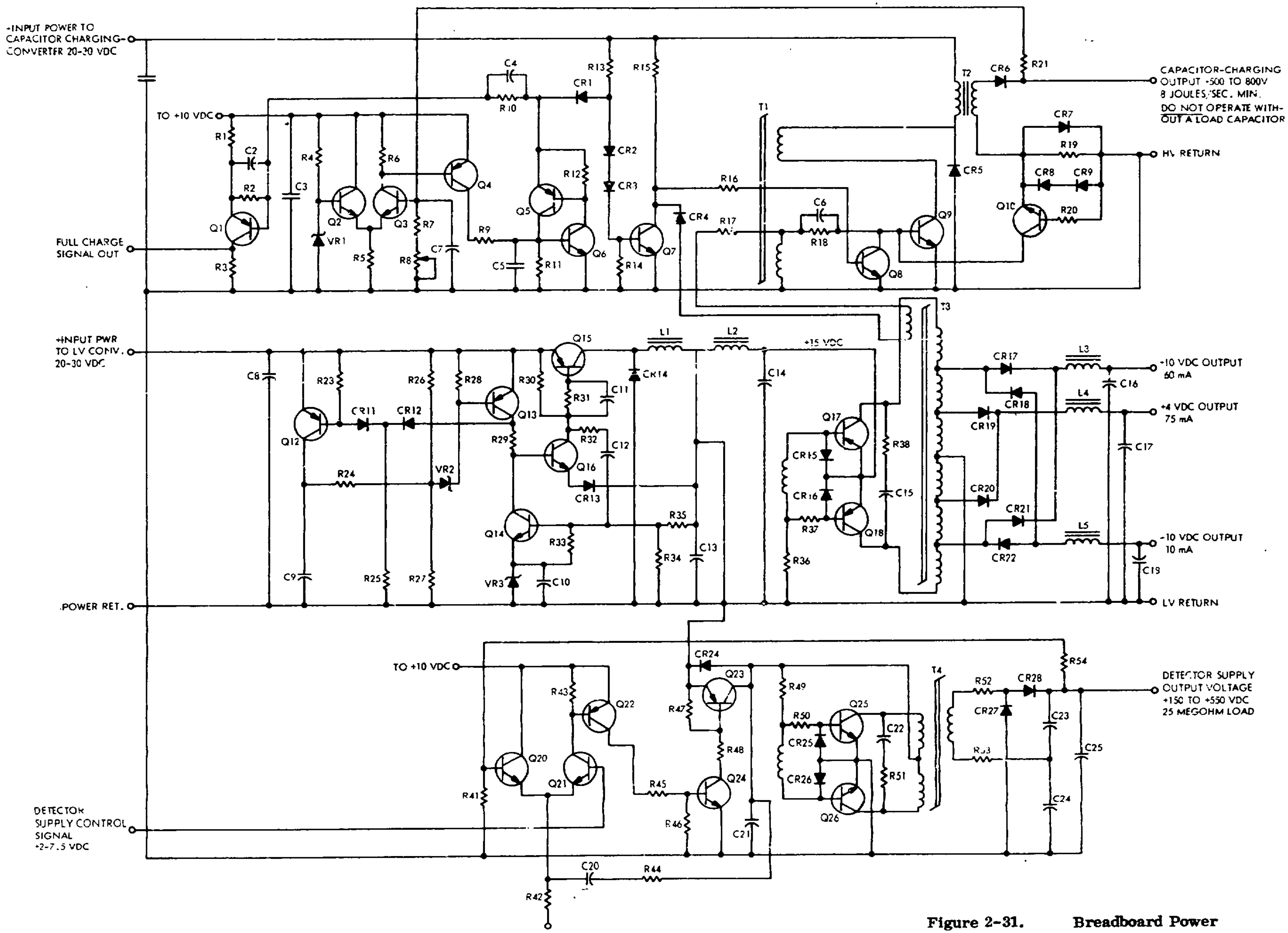


Figure 2-31. **Breadboard Power Supply Module Schematic**

Table 2-9. Breadboard Power Supply Electrical Stress Tabulation - Components

		Mfg. Ratings at Ta°=		Worst Case Circuit Stress		
Find No.	Description	Cap.	V	Volts	Current	Power
C1	Solid Tantalum	6.8 μf	35 V	30 V		
C2	Ceramic	1 nf	200 V	1 V		
C3	Solid Tantalum	1 μf	50 V	10 V		
C4	Ceramic	1 nf	200 V	10 V		
C5	Ceramic	0.047 μf	50 V	1 V		
C6	Ceramic	0.1 μf	50 V	5 V		
C7	Ceramic	220 pf	200 V	7 V		
C8	Solid Tantalum	6.8 μf	35 V	30 V		
C9	Solid Tantalum	6.8 μf	35 V	19 V		
C10	Solid Tantalum	15 μf	20 V	14 V		
C11	Ceramic	0.1 μf	50 V	13 V		
C12	Ceramic	2.2 nf	100 V	19 V		
C13	Solid Tantalum	15 μf	20 V	15 V		
C14	Solid Tantalum	15 μf	20 V	15 V		
C15	Ceramic	68 pf	200 V	30 V		
C16	Solid Tantalum	15 μf	20 V	10.5 V		
C17	Solid Tantalum	56 μf	6 V	4 V		
C18	Solid Tantalum	15 μf	20 V	10.5 V		
C20	Ceramic	1 nf	200 V	15 V		
C21	Solid Tantalum	1 μf	50 V	14 V		
C22	Ceramic	68 pf	200 V	28 V		
C23	Ceramic, HV Disc	2.2 nf	500 V	225 V		
C24	Ceramic, HV Disc	2.2 nf	500 V	225 V		
C25	Ceramic, HV Disc	0.02 μf	1000 V	550 V		

Table 2-9. Breadboard Power Supply Electrical Stress Tabulation - Components (Cont.)

		Mfg. Ratings at Ta°=				Worst Case Circuit Stress		
Find No.	Description	Volt	Imax	Pmax	@ T°	Volts	Current	Power
VR1	J1N4570A	OTC	@ 1 mA	400 mW	50°C	6.4 V	1 mA	6.4 mW
VR2	J1N964B	13 V ± 5%	24 mA	400 mW	50°C	13 V	1 mA<	13 mW
VR3	J1N964B	13 V	24 mA	400 mW	50°C	13 V	2 mA<	26 mW
CR1	J1N4148	75 V	150 mA	500 mW	25°C	7 V	4.6 mA	4.6 mW
CR2	1N4148					0.7 V	4.5 mA	4.5 mW
CR3	1N4148					0.7 V	4.5 mA	4.5 mW
CR4	1N4148					3.5 V	4.5 mA	4.5 mW
CR5	J1N4942	200 V	1 A		55°C	80 V	1 A PK	10 mW<
CR6	F15	1500 V	0.1 A	5 V @ 50 mA	55°C	1300 V	0.020	100 mW
CR7	J1N4148					1.5 V	Pulse	5 mW<
CR8	1N4148					0.7<	0.020	20 mW
CR9	1N4148					0.7<	0.020	20 mW
CR11	1N4148					0	1 mA<	1 mW<
CR12	1N4148					28 V	1 mA<	1 mW<
CR13	1N4148					4 V<	15 mA	15 mW
CR14	1N4148					30 V	75 mA	75 mW
CR15	1N4148					1 V<	6 mA	6 mW
CR16	1N4148					1 V<	6 mA	6 mW
CR17	1N4148					20 V	30 mA	30 mW
CR18	1N4148					20 V	4 mA	4 mW
CR19	1N4148					7 V	50 mA	50 mW
CR20	1N4148					7 V	50 mA	50 mW
CR21	1N4148					20 V	30 mA	30 mW
CR22	1N4148					20 V	4 mA	4 mW
CR24	1N4148					15 V	0	
CR25	J1N4148					1 V<	4 mA<	4 mW
CR26	1N4148					1 V<	4 mA<	4 mW
CR27	J1N4947	800 V	1 A		55°C	550 V	1 mA<	1 mW
CR28	1N4947					550 V	1 mA<	1 mW

Table 2-9. Breadboard Power Supply Electrical Stress Tabulation - Components (Cont.)

		Mfg. Ratings at Ta°=				Worst Case Circuit Stress		
Find No.	Description	Volt	Imax	Pmax	@ T°	Volts	Current	Power
Q1	J2N2907A	60 V	600 mA	400 mW	25°C	10 V	1 mA	5 mW<
Q2	J2N930	45 V	30 mA	500 mW	25°C	4 V	40 μa	5 mW<
Q3	2N930	45 V	30 mA	500 mW	25°C	4 V	40 μa	5 mW<
Q4	J2N2605	45 V	30 mA	400 mW	25°C	10 V	50 μa	5 mW<
Q5	2N2907A					10 V	4.5 mA	5 mW<
Q6	J2N2222A	40 V	800 mA	500 mW	25°C	10 V	4.5 mA	5 mW<
Q7	2N2222A					3 V	4.5 mA	5 mW<
Q8	2N2222A					1 V	Short pulse 1 mA< avg.	1 mW<
Q9	J2N4150	100 V	10 A	1.5 W	25°C	80 V	4 A PK	1.2 W PK 0.12 W avg.
Q10	2N2222A					2.5 V	1 mA	1 mW<
Q12	2N2907A					30 V	0	0
Q13	2N2907A					0.3 V	4 mA	1 mW<
Q14	2N2222A					13 V	1 mA<	1 mW<
Q15	2N2907A					31 V	75 mA	50 mW
Q16	2N2222A					15 V	15 mA	15 mW<
Q17	2N2907A					30 V	90 mA	25 mW
Q18	2N2907A					30 V	90 mA	25 mW
Q20	2N930					10 V	1 mA<	1 mW<
Q21	2N930					10 V	1 mA<	1 mW<
Q22	2N2907A					10 V	1 mA<	5 mW<
Q23	J2N2907A					15 V	22 mA	80 mW<
Q24	2N2222A					15 V	1 mA	10 mW<
Q25	2N2222A					27 V	11 mA	15 mW<
Q26	2N2222A					27 V	11 mA	15 mW<

Table 2-9. Breadboard Power Supply Electrical Stress Tabulation - Components (Cont.)

		Mfg. R. at Ta°=			Worst Case Circuit Stress		
Find No.	Description	Watt.	Volt		Volts	Peak Pwr	Avg. Pwr
	Resistors						
R1		1/8					5 mW<
R2		1/8					5 mW<
R3		1/8					5 mW<
R4		1/10					5 mW<
R5		1/8					5 mW<
R6		1/8					5 mW<
R7		1/10					5 mW<
R8		1/4					5 mW<
R9		1/8					5 mW<
R10		1/8					5 mW<
R11		1/8					5 mW<
R12		1/8					5 mW<
R13		1/8				12.6 mW PK	12.6 mW avg.
R14		1/8					5 mW<
R15		1/8				90 mW PK	9 mW avg.
R16		1/8				17 mW PK	5 mW<
R17		1/8					5 mW<
R18		1/4				273 mW PK	27 mW avg.
R19						15 mW PK	5 mW<
R20							5 mW<
R21		0.6	1000 V		800 V	40 mW PK	4 mW avg.
R23		1/8					5 mW<
R24		1/8					5 mW<
R25		1/8					5 mW<
R26		1/8					5 mW<
R27		1/10				14 mW	5 mW<

Table 2-9. Breadboard Power Supply Electrical Stress Tabulation - Components (Cont.)

		Mfg. Ratings at Ta°=		Worst Case Circuit Stress		
Find No.	Description	Watt	Volt	Volts	Peak Pwr	Avg. Pwr
R28		1/10				5 mW<
R29		1/8			47 mW	5 mW<
R30		1/8				5 mW<
R31		1/4			234 mW	30 mW<
R32		1/8				10 mW<
R33		1/10				5 mW<
R34		1/8				10 mW<
R35		1/10			12 mW	5 mW<
R36		1/8				5 mW<
R37		1/8			27 mW	5 mW<
R38		1/8				5 mW<
R41		1/10				5 mW<
R42		1/8				5 mW<
R43		1/8				5 mW<
R44		1/8				5 mW<
R45		1/8				5 mW<
R46		1/8				5 mW<
R47		1/8				5 mW<
R48		1/8			23 mW	5 mW<
R49		1/8			7 mW	5 mW<
R50		1/8			51 mW	10 mW<
R51		1/8				5 mW<
R52		1/8				5 mW<
R53		1/8				5 mW<
R54		1/2	600 V	550 V	61 mW	10 mW<

All transformers custom designed for intended application with >2X margins on voltage stress and rms current ratings.

Table 2-10. Test Data Sheet

Test No.	Parameter	Data			Remarks
	Input Voltage	20 VDC	24 VDC	30 VDC	
30°C	Output Voltage	801	801	801	3.8977J
	Charge Time	0.44	0.33 sec	0.25 sec	12.15 μfd
	Energy Del. Rate	8.858	11.81	15.59	Joules/sec.
	Full Chrg. Signal	9.67/0.1V	9.75/0.1V	9.88/0.1V	10 Meg Meterload +10 Meg Signal
	LV Conv. Input	12.5 ma	13.1 ma	14.3 ma	Operating Unloaded
	Resistive Load Efficiency	(0.25W)	(0.31W)	(0.43W)	
	Input Current	0.65	0.73	0.825	A
	Input Power	13	17.52	24.75	$V_{in} \times I_{in}$
	Output Voltage	739	768	728	V
	Output Current	0.0144	.0192	0.0287	A
	Output Power	10.64	14.74	20.89	$V_{out} \times I_{out}$
	Efficiency	81.8%	84.1%	84.4%	
	Corrected for LV	83.4%	85.6%	85.8%	

Table 2-11. Test Data for Deliverable Breadboard

Low-Voltage and Detector Outputs

	E_{1N} (Volts)	I_{1N} (ma)	V_{DET}	V_{CONTR}	V_{+10}	V_{-10}	V_{+3}	V For Undervolt Cuttoff
Room Temp.	20	73.4	150	1.99	9.79	-10.00	2.97	x
Room Temp.	20	87.2	550	7.47	9.77	-9.98	2.97	x
								19.1 Volts
Room Temp.	24	67.2	150	1.99	9.91	-10.12	3.01	x
Room Temp.	24	89.2	250	3.34	x	x	x	x
Room Temp.	24	72.0	350	4.71	x	x	x	x
Room Temp.	24	75.0	450	6.09	x	x	x	x
Room Temp.	24	77.7	550	7.47	9.89	-10.10	3.01	x
Room Temp.	30	63.0	150	1.98	10.08	-10.30	3.08	x
Room Temp.	30	72.0	550	7.47	10.07	-10.29	3.07	x

Table 2-12. Low Temp. Test Data Sheet

Test No.	Parameter	Data			Remarks
	Input Voltage	20 VDC	24 VDC	30 VDC	
-45°C	Output Voltage	804	804	804	3.927 Joules
	Charge Time	0.47	0.36	0.27	12.15 μfd
	Energy Del. Rate	8.35	10.91	14.54	Joules/sec.
	Full Chrg. Signal	9.43	9.53	9.63	
	Resistive Load Efficiency				
	Input Current	0.525A	0.58A	0.69	
	Input Power	10.5W	13.92W	20.7	$V_{in} \times I_{in}$
	Output Voltage	668V	765V	663	
	Output Current	.013A	.015	.0262	
	Output Power	8.684W	11.475W	17.37	$V_{out} \times I_{out}$
	Efficiency	82.7%	82.4%		
	Corrected P_{in} for LV	10.25	13.61	20.27	
	Corrected	84.7%	84.3%	85.7%	

Table 2-13. High Temp. Test Data Sheet

Test No.	Parameter	Data			Remarks
	Input Voltage	20 VDC	24 VDC	30 VDC	
+71°C	Output Voltage	800	800	800	3.888 Joules
	Charge Time	0.43	0.32	0.23	12.15 μfd
	Energy Del. Rate	9.04	12.15	16.9	Joules/sec.
	Full Chrg. Signal Tr to 5V	9.80V	9.91V	10.02V	
	LV Conv. Input	0.0133A	0.0137	0.0147	
	Resistive Load Efficiency	(0.266W)	(0.33)	(0.441W)	
	Input Current	0.61	0.68	0.20	
	Input Power	12.2	16.32	24	$V_{in} \times I_{in}$
	Output Voltage	699	730	710	
	Output Current	0.0138	0.0184	0.028	
	Output Power	9.646	13.43	19.88	$V_{out} \times I_{out}$
	Efficiency	79%	82.3%	82.8%	
	Corrected P_{in} for LV	11.934	15.99	23.56	
	Corrected	80.8%	84%	84.4%	

Table 2-14. Temp. Test Data - Low Voltage and Detector Power Supply

	E_{1N} (Volts)	I_{1N} (ma)	V_{DET}	V_{CONTR}	V_{+10}	V_{-10}	V_{+3}	V For Undervolt Current
+160°F 71.1°C	20		150					x
+160°F 71.1°C	20		550					x
								18.7
+160°F 71.1°C	24	68.5	150	1.96	10.03	-10.26	3.08	x
+160°F 71.1°C	24	70.8	250	3.32	x	x	x	x
+160°F 71.1°C	24	73.7	350	4.69	x	x	x	x
+160°F 71.1°C	24	77.1	450	6.07	x	x	x	x
+160°F 71.1°C	24	80.5	550	7.45	10.00	-10.24	3.07	x
+160°F 71.1°C	30	63.6	150	1.96	10.19	-10.43	3.13	x
+160°F 71.1°C	30	74.0	550	7.45	10.19	-10.42	3.13	x

Table 2-14. Temp. Test Data - Low Voltage and Detector Power Supply (Cont.)

	E_{1N} (Volts)	I_{1N} (ma)	V_{DET}	V_{CONTR}	V_{+10}	V_{-10}	V_{+3}	V For Undervolt Current
-50°F -45.6°C	20	64.2	150	1.97	9.59	-9.78	2.86	x
-50°F -45.6°C	20	79.6	550	7.45	9.59	-9.78	2.86	x
								19.6V
-50°F -45.6°C	24	63.2	150	1.97	9.68	-9.87	2.90	x
-50°F -45.6°C	24	65.7	250	3.33	x	x	x	x
-50°F -45.6°C	24	67.9	350	4.69	x	x	x	x
-50°F -45.6°C	24	78.0	450	6.06	x	x	x	x
-50°F -45.6°C	24	72.0	550	7.45	9.67	-9.85	2.87	x
-50°F -45.6°C	30	59.5	150	1.97	9.84	-10.02	2.95	x
-50°F -45.6°C	30	67.3	550	7.45	9.84	-10.03	2.95	x

TEST NOTES:

(1) It was determined by observation that a change in E_{in} from 20 VDC to 30 VDC had no effect on the value of the detector output (no effect on the first 3 digits as viewed on a Fluke 8000A). This was verified at 150V, 300V and 550V.

(2) All voltage measurements taken on non-current-carrying wires (e.g. 4-wires used for input, two carrying the current and two for sensing at the input terminals.)

(3) With the DET. output at 550V, which was found to be worst case both for LOW-VOLTAGE ripple and for DET. OUTPUT ripple, the output ripple was as follows:

(E_{in} = 24.0, loads = Full)

+10 Output = 45 mV p-p

-10 Output = 30 mV p-p

+3 Output = 6 mV p-p

DET. Output = ~850 mV p-p (With an "occasional" 1.3 volt p-p excursion

~5 millisec

(Used HP 1220A Scope)

(4) +10 Load = 167.2Ω

-10 Load = 1244 Ω

+6 Load = 29.7 Ω

Deliver Output Load = ZERO

2.8 RANGE COUNTER/DISPLAY MODULE

2.8.1 Packaging

The Range Counter/Display Module is a hybrid circuit packaged on a 2.25 x 1.63 x 0.035 alumina substrate. The total weight of the module is 0.07 pounds.

The hybrid circuit will utilize two custom-SOS chips to perform the logic, a quartz crystal, and two linear chips for driving LED's. R-C networks composed of thick film resistors and chip capacitors are used to generate timing waveforms. The tolerance of the SOS threshold voltage is greater than the required timing tolerance, consequently the resistors will be functionally trimmed to compensate for threshold voltage variations.

The fabrication of these circuits will combine chip-and-wire with custom or hybrid integrated package (H.I.P) hermetic sealing techniques. The custom seal approach is favored because the cost is lower and risk less. It will be used unless the associated capacitance degrades the performance below the requirements. The layout will be designed to permit use of either approach. The active devices will be contained within the hermetic enclosure, but resistors and capacitors may be internal or external to this enclosure. The crystal will be packaged by the vendor and soldered to the ceramic in a fashion similar to that used on a PC board.

The readouts, all LED devices, are mounted to a small substrate. The plane of the readouts is at the focal plane of the readout optics in the telescope assembly when the substrate is installed.

The Range Counter/Display Module is mounted in a depressed section of the telescope housing. Three pads in the housing have a resilient elastomer applied. When installed the elastomer is compressed by the substrate which is forced against the three retaining clips.

The combination of the plane defined by the three clips and the peripheral cast bosses locate this module in reference to the optical readout in the telescope.

Electrical connections to and from the module are made using flexprint wiring terminated at soldered pins. The entire assembly is conformally coated with a urethane material for moisture protection.

The hybrid approach was selected in preference to a standard printed wiring board with discrete components design because of size and weight savings, as well as minimized handling, assembly, and test requirements.

The "range readout" and the "minimum range set" information are processed in the range counter board and displayed on a four digit dual-in-line LED chip. The board and display are portions of the same assembly. The design concept has been to optically project the range information into the telescope rather than install electronic components within the telescope assembly. The physical object size of the LED readout display is approximately twice its desired projected size in the telescope reticle plane. Therefore, the projection system is designed to reduce the display image size in the reticle plane by a factor of two.

The display readout chip is flanked by two LED's, one of which indicates battery low fault condition and the other, the presence of multiple target returns as a result of the last laser ranging. The readout chip and the two LED's mount on an insulating board fitted with right angle brackets that screw to the telescope housing. The flexible printed wiring cable solders to the leads projecting through the insulating board and interconnects to the range counter board.

Because the display projection lens introduces an optical image reversal, the range display LED assembly is mounted both upside down and reversed left-to-right to give an erect image in the eyepiece of the sighting telescope.

2.8.2 Electrical Design

2.8.2.1 Description of Operation

The Range Counter/Display Module performs the following functions:

(1) Counts, stores, decodes, and displays the range (in meters) to the first target in the laser rangefinder field-of-view between the minimum and maximum range.

(2) Detects and displays the presence of multiple targets.

(3) Detects and displays a low battery condition.

(4) Generates the Time Programmed Gain (TPG) gate.

(5) Determines, in conjunction with the MIN RANGE potentiometer, the minimum range for accepting and processing target returns.

(6) Displays the minimum range setting in the range readout whenever the MIN RANGE switch is actuated.

(7) Provides the required delay between receipt of the START pulse and counter operation to compensate for system delays in receiver STOP circuitry.

2.8.2.1.1 Technical Characteristics

The technical characteristics of the Range Counter/Display Module are as follows:

Operating Voltage

Logic circuitry . . . . 12.0 $\pm$ 5%

Light Emitting Diode (LED) Display. . . . 4.0 VDC $\pm$ 10%

Temperature

Operating . . . . -50°F to +160° F

Storage. . . . . -70°F to +160° F

Maximum Range .... 9990 meters

Minimum Range .... 200 meters to 5 kilometers continuously variable with a resolution of 50 meters minimum.

Range Resolution .... 10 meters

Range Readout .... Direct, numeric in meters. 7-segment LED display

Multiple Target Display .... Single LED lamp. Indicates the presence of multiple targets between the minimum and maximum range and separated by more than 50 meters.

Battery Low Indicator .... Single LED lamp. Indicates a batterv input voltage of less than 21.0 ± 1 VDC.

2.8.2.1.2 Operating Mode

There are two (2) operating modes for the range counter circuitry:

(1) Ranging mode - External inputs are accepted by the range counter circuits for processing.

(2) Minimum Range Set mode - Internal signals are generated for continuously updating the range counter to indicate the setting of the MIN RANGE one-shot.

Refer to Figure 2-32 for the following descriptions. The operating mode is determined by the MINIMUM RANGE SW input. When not actuated, the input is an open circuit with represents a logic 0 at the input of U22. The output of U22 is a logic 1 which enables U38, U4, U11 and U17 to pass the system generated FULL CHARGE, START and STOP pulses.

When actuated (Minimum Range Set Mode) the MINIMUM RANGE SW input is a DC voltage of 20 to 30 volts DC which is divided down to a logic 1 input level

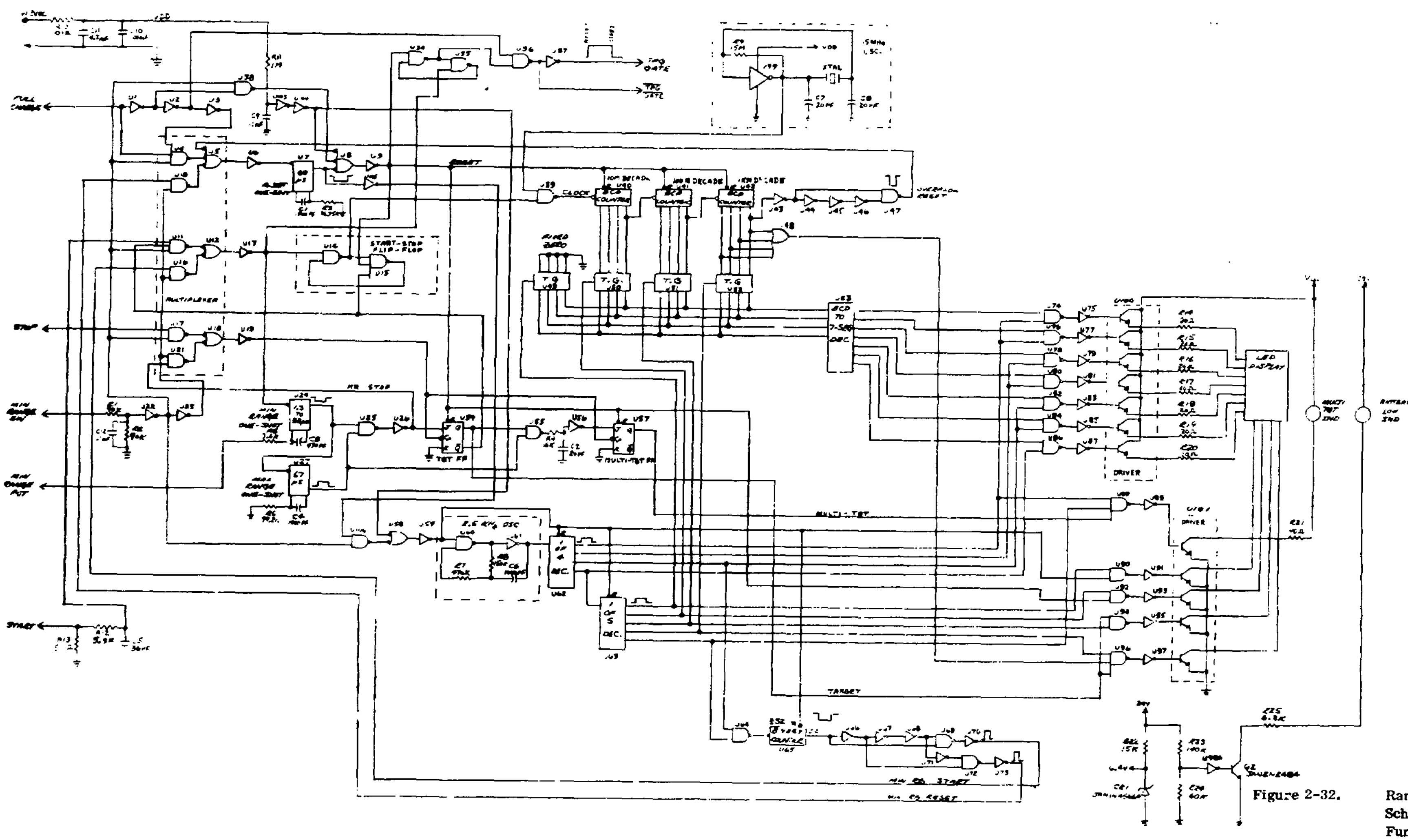


Figure 2-32. Range Counter/Display Schematic Diagram Functional Logic Diagram

by resistor divider R1 and R2. When a logic 1, the output of U22 is a logic 0 disabling the above mentioned gates, and the output of U23 is a logic 1 which enables U10, U16, and U21 to pass the internally generated MR RESET, MR START, and MR STOP pulses.

2.8.2.1.2.1 Ranging Mode

Upon application of power, the FULL CHARGE signal is a logic 0. The output of U1 is a logic 1 and the output of U38 is a logic 0. This logic 0 at the input of U8 causes the output of U9, which is the counter reset, to go to a logic 0 and hold all counters and flip-flops reset for the duration of the logic 0 at the FULL CHARGE signal input. After approximately one second, the FULL CHARGE signal goes to a logic 1, which removes the logic 0 at the input of U8 and in turn, removes the logic 0 (counter reset) at the output of U9.

When the FULL CHARGE signal goes to a logic 1, the output of U4 goes to a logic 0 and the output of U5 becomes a logic 1. Other inputs of U5 are at logic 1 levels (the overflow input to U5 is normally a logic 1 and becomes a logic 0 only if the range counter reaches its maximum count) and the output of U6 becomes a logic 0 triggering the RESET ONE-SHOT U7. The output of U7 becomes a logic 0 for approximately 60 microseconds and causes the output of U9 to again go to a logic 0 (counter reset condition) for 60 microseconds.

The START pulse input goes to a logic 1 at the instant of lasing. This pulse is delayed for approximately 70 nanoseconds by action of R12 and C5 (DELAY CKT) since the input of U11 rises exponentially to a logic 1 and its output changes when the transfer voltage is reached. This delayed start pulse if fed through U11, U12 and U13 to the input of the START-STOP FLIP-FLOP composed of U14 and U15. The output of U14 goes to a logic 1 level and causes U39 to pass the 15 MHz range clock to the range counter and the counting operation begins.

U40, U41 and U42 form a three decade BCD ripple counter. The period of the 15 MHz clock corresponds to a range increment of 10 meters.

Stop pulses are generated by the receiver section upon receipt of reflected laser energy from targets in the field-of-view. Only those targets between the minimum and maximum range will be recognized by the range counter in the following manner.

The start pulse output of U13 that operates the START-STOP FLIP-FLOP and initiates the counting operation also triggers the MIN RANGE ONE-SHOT (U24).

The output of U24 triggers the MAX RANGE ONE-SHOT U27. The output of U26, therefore, only goes to a logic 1 after the MIN RANGE ONE-SHOT has returned to a logic 1 level and during the period of the MAX RANGE ONE-SHOT.

The MIN RANGE ONE-SHOT period is adjustable by means of the remote MIN RANGE potentiometer from 200 meters (1.3μsec) to 5 kilometers (33μsec).

When the output of U26 becomes a logic 1, at the end of the MIN RANGE ONE-SHOT period, it enables the TARGET FLIP-FLOP U54. Upon receipt of a STOP pulse input the output of U19 goes to a logic 0 and clocks the TARGET FLIP-FLOP and the $\bar{Q}$ output becomes a logic 0 which resets the START-STOP FLIP-FLOP and halts the counting action by inhibiting the range clock gate U39. Once the TARGET FLIP-FLOP has operated, its Q output is ANDED with the MAX RANGE ONE-SHOT output at the inputs of U55 to enable the J input of the MULTIPLE TARGET FLIP-FLOP U57, after a 330 nanosecond (50 meter) delay provided by R4 and C2. The MULTIPLE TARGET FLIP-FLOP can therefore only be toggled by the stop pulse 330 nanoseconds after the TARGET FLIP-FLOP has operated and during the MAX RANGE ONE-SHOT period.

Upon receipt of the STOP pulse then, the range counter (U40, U41 and U42) contains the BCD data indicating the target range. Had no STOP pulse been received, the range counter would have counted to its maximum count and the falling edge of the 8 Kilometer bit (which occurs at 10 km) would have generated at logic 0 pulse at the output of U47. This pulse is fed to U5 which retriggers the RESET ONE-SHOT and resets the counter logic.

The range data stored in the BCD range counter (U40, U41 and U42) is sequentially multiplexed to the input of a BCD to 7-segment decoder (U53) by transmission gates U49 through U52. A fixed ZERO is also multiplexed to the decoder for the fixed zero in the range display.

After a power on reset generated by R11, C9, U103 and U104, the output of U59 becomes a logic 1 and gates ON the 2.5 kHz oscillator comprised of U60 and U61 and associated components. The square wave output of U61 triggers a one-of-four counter-decoder (U62). The outputs of U62 sequentially become logic 1 levels for the period of the 2.5 kHz clock.

The outputs of U62 sequentially enable the 7-segment decoder outputs (U53) to pass the SEGMENT ENABLE outputs through gates U74 through U87. Two segments are enabled at a time except for segment g which is enabled individually. The fourth output of U62 clocks a one-of-five counter decoder

(U63) at the trailing edge. The outputs of U63 become logic 1 levels sequentially for the period of the clock input. These outputs are used to enable transmission gates U49 through U52, and also to enable the proper character enable output through gates U90 through U97. Therefore, when the FIXED ZERO data is being selected by transmission gate (U49) and decoded to 7-segment format, the FIXED ZERO (character 1) is being enabled by U90 and U91.

When the 10's decade is being selected by transmission gate U50, the 10M digit (character 2) is being selected by gates U92 and U93, and so on for the remaining characters. (Note: The purpose of this strobing technique is to obtain maximum LED display efficiency by driving at high peak currents at low duty cycles.)

Character 1 gate U90 is enabled whenever the power is on. Character 2 is enabled whenever the counter reset is a logic 1. Character 3 is enabled (U94) whenever the TARGET FLIP-FLOP has toggled indicating the receipt of a target return. Character 4 (the 1 kilometer decade), gate U96, is enabled whenever a target has been detected and the 1 kilometer decade counter (U42) is not at a zero count. This character enabling logic, therefore, prevents displaying insignificant zeroes. Further, this strobing technique will continue until power is removed from the counter logic.

During the period that the FULL CHARGE signal is a logic 0, the output of U36 is a logic 1 and the output of inverter U37 (TPG gate) is a logic 0. Cross-coupled gates U34 and U35 form a flip-flop. The output of U34 is set to a logic 1 level at the counter reset time and becomes a logic 0 at the START time. When the FULL CHARGE signal becomes a logic 1, both inputs to U36 are logic 1 levels and the output of U36 becomes a logic 0 forcing the output of U37 to a logic 1 level. Upon receipt of a START pulse, the output of U34 becomes a logic 0 and forces the output of U37 to a logic 0 level.

2.8.2.1.2.2 Minimum Range Set Mode

Whenever the MINIMUM RANGE SW input is a logic 1, internally generated reset, start, and stop pulses are used to control the range counter logic. The output of U22 becomes a logic 0 and the output of U59 goes to a logic 1 level thereby turning on the 2.5 kHz oscillator. The logic 1 output of U23 enables select gates U10, U16, and U21 to pass the internally generated MR RESET, MR START and MR STOP pulses. The one-of-four counter decoder (U62), and the one-of-five counter decoder (U63) begin to operate when the 2.5 kHz oscillator is turned on.

When the fifth output of U63 AND the third output of U62 are logic 1 levels, the divide by 32 binary counter U65 is clocked by U64. Upon reaching its maximum count, the binary counter generates a CARRY OUT pulse which is differentiated by U66 through U73. A pulse is generated at the output of U73 coincident with the leading edge of the CARRY OUT pulse, and a pulse is generated at the output of U70 coincident with the trailing edge of the CARRY OUT pulse. The output of U73 is used as the MR RESET pulse and resets the range counter logic.

The output of U70 is the MR START pulse and starts the counting operation, and also to trigger the MINIMUM and MAXIMUM RANGE ONE-SHOTS. The output of U23 goes to a logic 1 level at the end of the MINIMUM RANGE ONE-SHOT period and this is fed through U21, U18, and U19 to trigger the TARGET FLIP-FLOP (U54). The $\overline{Q}$ output of U54 (TARGET FLIP-FLOP) stops the counter in the same manner as in the Ranging Mode.

The counter now contains range information corresponding to the setting of the MINIMUM RANGE ONE-SHOT and this data is strobed to the display in the usual manner, until the CARRY OUT pulse is again generated by binary counter U65 which repeats the resetting, starting, and stopping action. This action is repeated as long as the MINIMUM RANGE SW input remains at a logic 1 level. The divide by 32 counter is used to provide a relatively long time (256 ms) between updating of the range display so that the 10's decade can be easily read.

As an example: if the updating occurred at a rapid rate and the minimum range setting was alternating between 740 and 750 meters, the 10m decade would rapidly alternate between a 4 and a 5. To the operator this would appear as if all segments involved in these two numbers were there simultaneously and would appear as a 9. Slowing down the updating rate allows the operator to recognize the 4 and the 5.

2.8.2.2 Input-Output Specifications

2.8.2.2.1 Inputs

The Range Counter/Display Module accepts the following inputs: (Note: Logic levels are SOS-CMOS compatible and are defined as: logic 0 = 0.1 V_{DD} max, logic 1 = 0.8 V_{DD} min).

(1) FULL CHARGE SIGNAL - A logic 0 for approximately one second during the energy storage capacitor charging interval goes to a logic 1 at the end of approximately one second when a full charge condition is reached.

(2) START PULSE - A logic 1 level pulse having the following characteristics:

Pulse width	-	300 ns max
Rise time	-	5 ns max
Fall time	-	100 ns max

(3) STOP PULSE - A logic 1 pulse having the following characteristics:

Pulse width	-	40 ns min
Rise time	-	10 ns max
Fall time	-	200 max

(4) MIN RANGE SWITCH - A DC voltage of 20 to 30 VDC when MIN RANGE switch is activated, an open circuit when MIN RANGE switch is deactivated.

(5) MIN RANGE POT - A variable resistance to ground such as:

Minimum resistance	-	50Ω
Maximum resistance	-	50 kΩ

(6) BATTERY - A DC voltage of 20 to 30 VDC.

2.8.2.2.2 Outputs

The Range Counter/Display Module provides the following signal outputs:

TPG gate - A logic 1 level pulse coincident with receipt of FULL CHARGE signal; returns to logic 0 upon receipt of START pulse.

2.8.2.3 Schematic

Range counter functional logic is shown in Figure 2-32.

2.8.2.4 Parts List

The range counter parts list is shown in Table 2-15.

Table 2-15. Range Counter Parts List

PARTS LIST	RCA — RCA CORPORATION • NEW YORK, NY — BURL., MA. PLANT	REVISION DATE	PL	REV LTR

LIST TITLE: RANGE COUNTER	PREPARED BY W. Roberts DATE 10-9-7?	REL	CODE IDENT NO. 49671	SHEET 1 OF 4 SHEETS
	CHECKED BY DATE		CONTRACT NO.	

FIRST MADE FOR	NEXT ASSEMBLY	USED ON AN/GVS-5	DESIGN ACTIVITY APPD DATE

REVISIONS

LTR	DESCRIPTION	DATE	APPROVED	LTR	DESCRIPTION	DATE	APPROVED

INTERPRET SYMBOLS USED AS FOLLOWS:

UNITS OF MEASURE (UM)	QUANTITIES	SYMBOL
A — Inches B — Feet C — Yards D — Ounces E — Pints F — Quarts G — Gallons H — Barrels J — Pounds L — Pair M — Set N — Kit P — Roll R — Box, Case T — Each	X — Applicable document O — For ref only	U — Govt or customer furnished K — Govt or customer furnished and installed * — Vendor item. See specification or source control drawing.

RCA 2400-3 (4-71) 7086

Table 2-15. Range Counter Parts List (Cont.)

PARTS LIST	RCA — RCA CORPORATION NEW YORK, NY — BURL, MA, PLANT	REV LTR	CODE IDENT 49671	PL	SHEET 2

ITEM OR FIND NO.	QTY REQD PER DASH NO. -506	-504	-503	-502	-501	U M	CODE IDENT	PART OR IDENTIFYING NO.	SPECIFICATION	NOMENCLATURE OR DESCRIPTION	SYM
R1					1					90K, 1/8W RESISTOR	
R2					1					90K, 1/8W RESISTOR	
R3					1					86.75K, 1/8W RESISTOR	
R4					1					16K, 1/8W RESISTOR	
R5					1					3.6K, 1/8W RESISTOR	
R6					1					99.2K, 1/8W RESISTOR	
R7					1					470K, 1/8W RESISTOR	
R8					1					150K, 1/8W RESISTOR	
R9					1					15M, 1/8W RESISTOR	
R10					1					100Ω, 1/8W RESISTOR	
R11					1					1M, 1/8W RESISTOR	
R12					1					6.6K, 1/4W RESISTOR	
R13					1					1K, 1/8W RESISTOR	
R14-R19					6					20Ω, 1/8W RESISTOR	
R20/R21					2					40Ω, 1/8W RESISTOR	
R22					1					15K, 1/8W RESISTOR	
R23					1					140K, 1/8W RESISTOR	
R24					1					60K, 1/8W RESISTOR	
R25					1					6.2K, 1/8W RESISTOR	

RCA 2401-3 (4-71) 7097

Table 2-15. Range Counter Parts List (Cont.)

PARTS LIST	RCA	RCA CORPORATION NEW YORK, NY — BURL, MA. PLANT	REV LTR	CODE IDENT 49671	PL	SHEET 3

ITEM OR FIND NO.	QTY REQD PER DASH NO. -505	-504	-503	-502	-501	U M	CODE IDENT	PART OR IDENTIFYING NO.	SPECIFICATION	NOMENCLATURE OR DESCRIPTION	SYM
C1					1					1000 pF, 10V CAP	
C2					1					20 pF, 10V CAP	
C3					1					470 pF, 10V CAP	
C4					1					1000 pF, 10V CAP	
C5					1					36 pF, 10V CAP	
C6					1					1000 pF, 10V CAP	
C7					1					20 pF, 10V CAP	
C8					1					20 pF, 10V CAP	
C9					1					.1 μF, 10V CAP	
C10					1					.01 μF, 20V CAP	
C11					1					4.7 μF, 20V CAP	
C12					1					.1 μF, 10V CAP	
U1					1			TCC 060 100		RANGE COUNTER LSI	
U2					1			TCC 060 101		DECODER LSI	
U3					1			CD4011		QUAD NAND GATE	
VR1					1			MZC9.1B10	MOTOROLA	9.1 V ZENER	
U4					1			CA3081		HEX TRANSISTOR ARRAY	
U5					1			CA3082		HEX TRANSISTOR ARRAY	
Z1					1			2375046		15 MHz CRYSTAL	

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Table 2-15. Range Counter Parts List (Cont.)

PARTS LIST RCA — RCA CORPORATION · NEW YORK, NY — BURL, MASS. PLANT — REV LTR: — CODE IDENT: 49671 — PL — SHEET 4

ITEM OR FIND NO.	QTY REQD PER DASH NO. -505	-504	-503	-502	-501	U M	CODE IDENT	PART OR IDENTIFYING NO.	SPECIFICATION	NOMENCLATURE OR DESCRIPTION	SYM
U6					1			5082-7414	H.P.	LED DISPLAY	
CR1					1			5082-4684	H.P.	LED	
CR2					1			5082-4684	H.P.	LED	
Q1					1			JAN 2N2222A		TRANSISTOR	

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2.9 CONTROLS, INTERLOCKS, AND FAULT ISOLATION

2.9.1 Description of Controls and Interlocks

Controls

All AN/GVS-5 ( ) user-operated controls are attached to the control panel of the equipment, and are disposed so as to provide ready access and efficient operation Table 2-23 lists their salient features:

Table 2-23. Salient Features of AN/GVS-5 ( ) Controls

Reference Designation	User Function	Operating Mode
S1	Power On/Off	Bar-knob-operated rotary switch connects internal power (battery) or external power
S2	Fire	Pushbutton operated with right index finger
S4	Min. Range On	Pushbutton operated with left index finger used with R1 for display turn-on
S5	Reticle Light	Pushbutton operated with right thumb, lights reticle
R1	Min. Range Set	Thumb-wheel operated with right thumb, varies min. range
R2	Reticle Light Dim.	Rotary bar knob operated with left thumb, varies reticle light brightness

All of the user-operated control components have been selected primarily for minimum size and weight in a MIL spec construction, and to provide the required electrical function at minimum cost.

S2, and S4 switches are of a double-pole, double-throw configuration; S1 and S5, are of single-pole, single-throw configuration. S2, S4 and S5 are actuated by an external, sealed pushbutton assembly. The switching elements comprise sub-miniature basic switches (Microswitch 1SX-type), ganged together for double pole configuration and supported by suitable brackets to accurately position the switch elements and their standard blade actuators relative to the pushbutton induced actuation force. This concept allows initial design flexibility, high manufacturability, compactness and lightweight in the finished equipment, and reduced customer logistics problems with field servicing.

Compared to the pushbutton switches, S1 presents a more difficult combination of design requirements, primarily because of the need for silent operation, and for rotary shaft actuation in combination with the previously-mentioned weight and size constraints. An SR-20 type switch per MIL-S-3786 has been selected to meet all requirements. This switch, M3785/20-035, -040, or -042, has a 0.5 in. lbs. minimum rotational torque limit for a 60 degree throw. It will switch 200 ma resistive, at 28 volts DC and will carry in excess of 5 amps at the same voltage, continuously, with a life in excess of 25,000 cycles over the range of -65°C to +85°C. Pressure-sealing of the through-panel lead paths is accomplished by use of the M5423/09-03 (non-RFI) shaft seal boot.

Interlock switches S3A and S3B, located internally, are required for hazard protection when the AN/CVS-5 ( ) cover is removed, at which time they disconnect prime 24V power, and discharge the PFN capacitor (800V) to ground. Microswitch 1SX basic switches are again used, in combination with standard leaf actuators to obtain the size/weight/standardization advantages mentioned earlier. Microswitch has verified that the basic switch contact rating and dielectric strength are satisfactory in the 800V environment. Also, an in-house test exposing the basic switch to 1600 VDC for two minutes caused no breakdown.

The interlock switches are mounted on the trigger circuit board and are directly actuated by the cover. An integral feature to defeat the switches for cover-off servicing has been eliminated to reduce weight and to avoid the high cost of a special microswitch assembly. To defeat the switches, a "tool" such as a rubber band or a clip will be specified. The Min. Range Adjust potentiometer (R1) must provide high resolution, high stability, a large resistance value (60K), and wire-wound construction in a small, light, moderate-cost MIL-type device, including the necessary features for environmental sealing. The Bourns type 3510S potentiometer is specified because it provides the required high resistance and environmental sealing features within the above-mentioned limits. Since pressure sealing must be provided by the potentiometer rather than the shaft seal (see sealing discussion later on), these provisions will be built in by Bourns as standard part modifications. Specifically, an 0-ring panel seal and 0-ring shaft seal are added as well as body sealing with clear epoxy sealant. The reason for the body seal is that the shaft seal is good to only 5 psi. Thus while it is adequate for water immersion protection, at pressure differentials greater than 5 psi, the body seal is necessary to prevent leakage. The panel seal is adequate to a 15 psi differential. These features will seal the shaft against water entering the component interior during the three-foot deep water immersion requirement, and seal the mounting bushing-potentiometer body leak path at altitude.

Reticle light brightness is controlled by R2, a style RV6 potentiometer per MIL-R-94. The Allen-Bradley version (Type GA) is available with a sealed body, and an integral 0-ring panel and shaft seals which are effective to fifteen psig minimum. The RV6 style potentiometer is small (0.5 diameter), has multiple vendors, meets all environmental requirements without modification, and is low cost.

Pressure/EMI Sealing

Several types of MIL-B-5423 sealing boots will be used to seal S4, and S5 pushbutton actuators, and R1, R2, and S1 rotary shaft/panel seals against pressure leaks. The pushbutton assemblies, of self-shielding design, will use a small non-RFI-type pushbutton boot M5423/10-01, which pressure-seals bilaterally to fifteen psig. The shaft of S1 will use the non-RFI-type rotary shaft sealing boot, M5423/09-03, which seals to fifteen psig bilaterally, as above. Since R1 and R2 potentiometers do not contain features to absolutely remove the possibility of EMI propagation, EMI-shielding capability can be enhanced by the M5423/09-09 EMI-type rotary shaft sealing boot. Use of the latter boot, however, requires that all pressure sealing duties be performed solely by the seals of the potentiometers, rather than their functioning as a backup to the boot seal. The M5423/09-09 boot has not been qualified to meet the fifteen psig pressure seal limit normally required of its family.

Control Knobs

All user controls except S2, S4, and S5 require knobs for tactual and visual coupling, and will necessarily be of unique form. They will meet MIL-K-3926 as the material and performance but will require custom molding to RCA requirements. Attachment will be via set screws, in an aluminum insert, one bearing on a flatted shaft.

2.9.2 Electrical Design

2.9.2.1 Controls and Interlocks

Laser rangefinder controls and interlocks are connected as shown in Figure 2-44. The ratings for the switches are shown below:

S1 - 5 amp resistive load
3 amp inductive load
2.5 amp lamp load
at sea level for 28 VDC.

S2 - S5 - 7 amp resistive load
4 amp inductive load
2.5 amp lamp load
at sea level for 28 VDC.

Surge current rating for all switches is 24 amperes for one millisecond.

Since the capacitor charging converter requires the +12 volt DC output in order to begin charging and since the response time of the +12 volt DC supply is in the tens of milliseconds, the switches will have stopped bouncing before the high charging current begins.

The switches need, therefore, only handle the power supply input filter capacitor charge current pulse and the low voltage power supply current.

The filter capacitor charge current pulse is 15 amperes for 10 microseconds which is well below the surge rating of the switches.

The low voltage power supply current is less than 100 milliamperes, also well below the switch ratings.

Switch S3B connects the PFN capacitor voltage through a 20 kilohm resistor to ground when the cover is removed. The peak current will be 800V/ 20,000 = 0.04A, worst case. In normal operation the capacitor is discharged by laser firing upon reaching the full charge level so that the probability of any current flow through S3B is very low.

Since the breakdown voltage, contact-to-contact is greater than 1000 VDC, switch S3B is capable of performing the safety interlock function for the PFN capacitor.

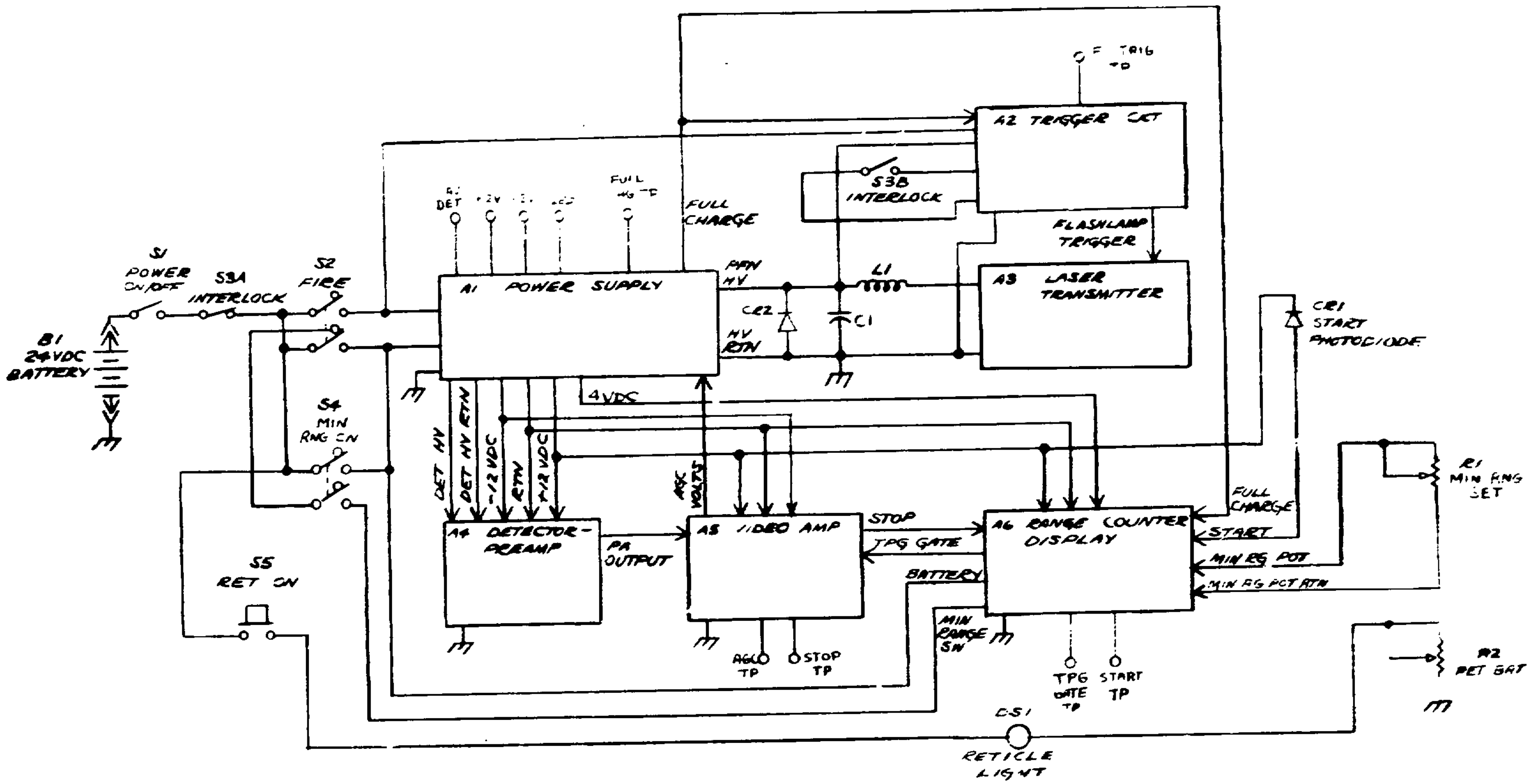


Figure 2-44. Overall AN/GVS-5 ( ) Schematic Diagram

Switch S5 connects battery voltage to the reticle lamp through the reticle brightness control to ground.

The lamp surge current can be 10 to 12 times the average current level. The average current is 40 milliamperes, therefore, S5 must be capable of switching (12) (40) milliamperes or 0.48 amperes. This is well below the rating for S5.

R1 (75k ±3%), the MIN RNG SET potentiometer, changes the pulse width of the MIN RNG one shot. R1 is in series with a 1.8 kilohm fixed resistor. The maximum voltage across the two resistors is 10.5 volts. Maximum power dissipated in R1 occurs when R1 is 1.8k.

$$P_{R1} = \frac{\left(\frac{1.8k}{3.6k} \times 10.5\right)^2}{1.8k} = \frac{(5.25)^2}{1.8k} = 15.3 \text{ mW}$$

The power rating for R1 is 1.0 watt at +70°C.

Potentiometer R2 (250Ω ±10%) controls the brightness of the reticle light. As seen from the reticle circuit discussion, the maximum voltage across R2 is 10 VDC and the maximum average power through R2 is 346 mW at +70°C. R2 is rated at 500 mW at +70°C and has a maximum voltage rating of 300 VDC at 10,000 feet altitude. The actual loading of R2 is, therefore, well below its ratings.

2.9.2.1.1 Reticle Circuit

The reticle circuit consist of a lamp, dimmer pot and a push button switch as shown in Figure 2-45.

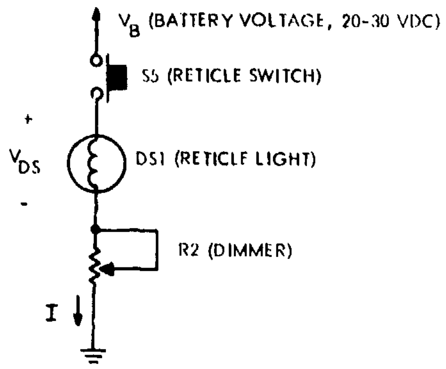


Figure 2-45. Reticle Circuit

The switch is rated over a temperature range of -67° F to +185° F at 2.5 amps. The lamp is rated at 28V, 40 mA, it has a light output of .4 mean spherical candle power (M.S.C.P.) and a life of 10,000 hours. The current, light output and life are all a function of lamp voltage and are not noticeably affected by changes in temperature between -50° F and +160° F. Table 1 shows how current, light and life are affected by lamp voltage.

Lamp Voltage VDC	Current mA	Light Output M.S.C.P.	Lamp Life Hours
20	33	.12	400,000
24	37	.24	35,000
28	40	.40	10,000
30	41	.50	2,000

To show the effects of temperature on current, a 28V, 40 mA lamp was placed in a temperature chamber and run continuously from a 28 volt supply outside of the chamber between -50° F and +160° F. The lamp was at -50° F for more than one hour and at +160° F for almost two hours. A current of 42 mA was monitored continuously. (Since the filament temperature is of the order of 5000° F, a change in ambient of 110° F could be expected to have little effect.)

The lamp dimmer variable resistor has a maximum resistance of 250Ω ± 10%. It is rated at 500 mW at +70° C. At -50° F the maximum change in resistance is +5.5% making the worst case resistance at that temperature 250Ω + 15.5% or 290Ω. At +160° F the maximum change in resistance is ±2% making the worst case resistance at that temperature 250Ω + 12% or 281Ω. The most power is dissipated in R2 when V_B is 30 volts and R2 is at its maximum resistance. At this point V_{DS} is between 21 and 22 volts and I is 35 mA. At -50° F the worst case power dissipated in R2 is

$$(35\times10^{-3})^2\,(290) = (1.23\times10^{-3})\,(290) = 357 \text{ mW}$$

At +160° F the worst case power dissipated in R2 is

$$(35\times10^{-3})^2\,(281) = (1.23\times10^{-3})\,(281) = 346 \text{ mW}$$

2.9.2.2 Fault Isolation Philosophy

Fault isolation to a module is provided by test points located on each module for monitoring the rangefinder voltages and timing and control signals using standard test equipment. Test points are provided for the following voltages and signals:

(1) Battery voltage.
(2) PFN high voltage.
(3) Detector high voltage.
(4) +12 VDC
(5) -12 VDC
(6) +4.0 VDC
(7) AGC voltage.
(8) Full charge signal.
(9) Flashlamp trigger.
(10) Preamplifier output.
(11) Video Amplifier output.
(12) Start pulse.
(13) TPG Gate

The laser transmitter output energy will be monitored by means of a special test set (Figure 2-46) that indicates an energy level of more than 15 millijoules by illuminating a green indicator lamp. Energy levels detectable by the test set but below 15 millijoules, would cause a red indicator lamp to be illuminated. Failure of either of these lamps to illuminate upon laser operation would, indicate extremely low or no laser output energy. The test set would also contain a presettable counter that is started upon receipt of the transmitter output pulse. When the range counter reaches the range preset by thumbwheel switches, located on the test set, a light-emitting diode is pulsed on. This light pulse is optically coupled into the rangefinder receiver optics to simulate a target return. The range readout in the rangefinder displays the range indicated by the test set thumbwheel switches if the rangefinder is operating properly.

Operation of the range counter can be verified by actuation of the MIN RANGE SET switch and adjustment of the MIN RANGE control. The rangefinder range readout displays the setting of the minimum range gate if operating properly. The range counter uses identical circuitry, with the exception of input multiplexing logic, for the ranging mode and the MIN RANGE SET mode, and provides a nearly complete check of range counter logic circuits.

SECTION 5

ACCESSORIES

5.1 CARRYING CASE

5.1.1 Requirements

The carrying case for the Hand Held Laser Rangefinder, (HHLR) will be lightweight and will properly support the equipment during transport by an individual soldier. It will store a Rangefinder (HHLR), battery, and lens cleaning kit.

The carrying case will be a rugged and lightweight container fabricated from non-nutrient, waterproof materials.

5.1.2 Description

The carrying case, see Figure 5-1, will be fabricated from a high impact plastic and will contain the following features:

Exterior: (1) A ruggedized closure and latch arrangement to assure proper alignment of the case and rainproof the cover.

(2) A hinged cover to prevent dropping or losing the cover. The separation of the cover and case will be such that the soldier will have proper gripping area in order to remove the HHLR from its case with ease.

(3) Shoulder strap.

Interior: (1) Shock pads to properly position the HHLR in its upright or vertical position.

(2) Battery holder clip or cavity located in the cover of the case.

(3) Lens cleaning kit holder clip or cavity located in the cover of the case.

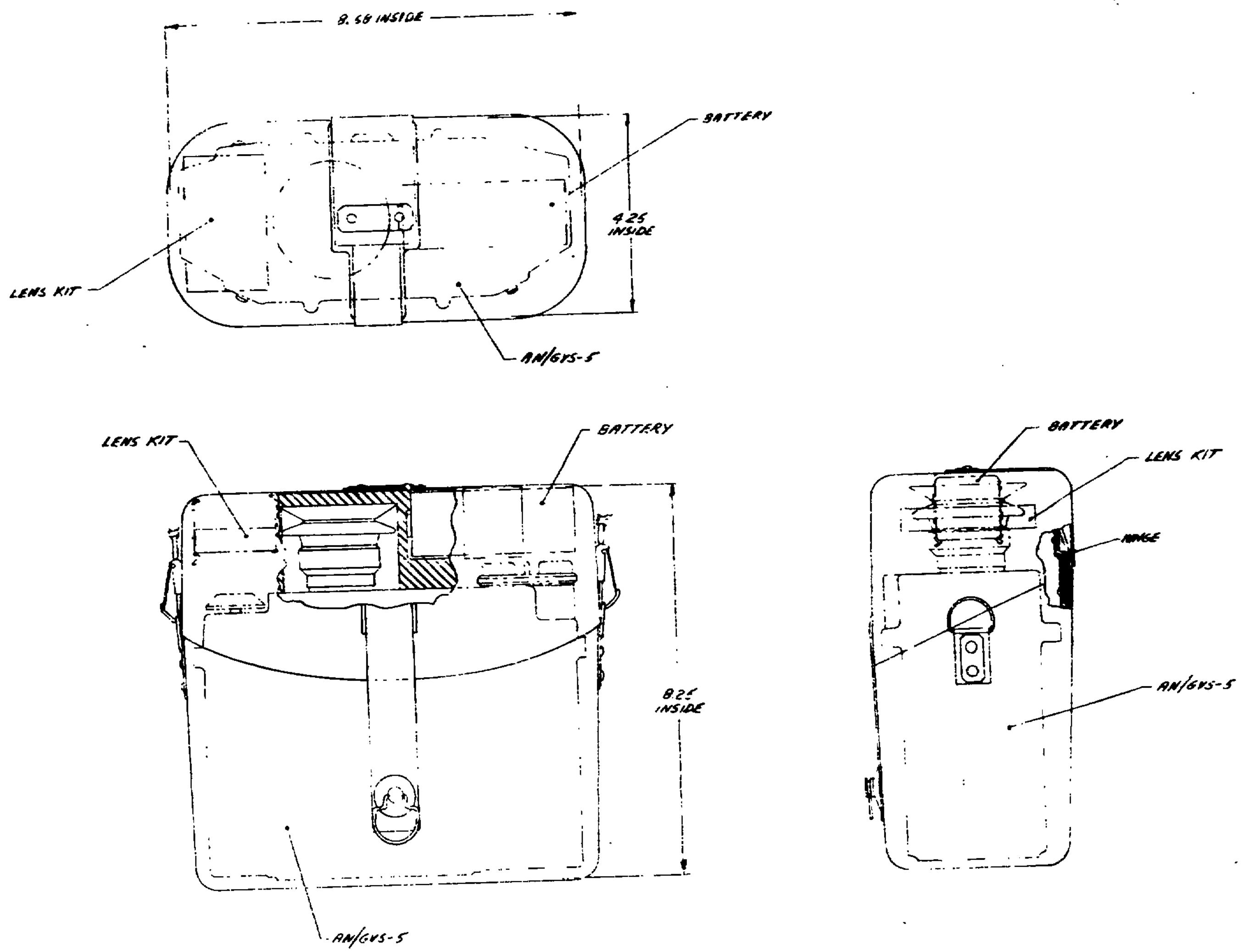


Figure 5-1. Carrying Case - AN/GVS-5 ( ) Vertical Mount

Note: (1) Utilization of clips or cavities to contain the battery and lens cleaning kit will assure the easy removal of these items.

(2) Locating the battery and lens cleaning kit in the cover of the case makes them easily accessible and makes the case more compact. This is by virtue of using what would otherwise be wasted volume created because of the height of the protruding eyepiece on top of the HHLR.

(3) An alternate design of the carrying case, Figure 5-2, is being considered wherein the HHLR would be positioned vertically within a case that would open along the vertical dimension in lieu of the previously proposed opening on the horizontal dimension.

With the parting surface of the case in the vertical plane, the HHLR and equipment would be more fully exposed when opened, allowing the soldier full accessibility to the equipment when viewing a possible target. The case would open in front of the soldier.

This design may result in a lower fabrication and tooling cost and would provide a better means for positioning the HHLR within the case.

5.2 TRANSIT CASE

5.2.1 Requirements

The transit case for the Hand Held Laser Rangefinder (HHLR) and associated equipment will be lightweight, of minimum size, and watertight. It must be of rugged design to contain and protect the HHLR during all modes of transportation and storage.

The case will be fabricated from non-nutrient, waterproof materials and will conform to RDD-STD-2-Cases, Transit and Combination for Electronic Command Equipment. The transit case will have provisions to store the following items:

(1) 1-HHLR in its carrying case.
(2) 1-Adapter bracket for mounting the AN/PVS-4 and AN/TVS-5 NV Sight
(3) 2-Spare Batteries
(4) 1-External power cable with connectors

The transit case and its support cushions will be capable of meeting the following environmental conditions when in the transit configuration:

(1) Shock: MIL-STD-810B Method 516, Procedure II, (Includes 48" drop test - Maximum internal equipment response 35 gs)

(2) Vibration: MIL-STD-810B, Method 514, Procedure XI, Part 2

(3) Temperature: -70°F to +160°F Storage

(4) Immersion: MIL-STD-810B, Method 512 (3 feet of water, 2 hours duration minimum).

(5) Altitude: Ground Level to 50,000 feet. Maintain minimum 6.7 psia within case at 50,000 feet.

5.2.2 Description

The transit case (see Figure 5-3) will conform to the requirements of RDD-STD-2 and will be fabricated from a high impact plastic and/or aluminum. The following features will be incorporated into the design of the transit case.

Exterior: (1) Rub rails or equivalent to protect the corners, latches, handles, humidity indicator and pressure relief valve during handling and transportation.

(2) Extruded aluminum closure or equivalent to seal the transit case and minimize any distortion.

(3) Spring loaded or mechanical latches on the case to assure a positive seal and watertightness. (10 NIELSEN VHC-250-68S-Z0 or equivalent Design Load approx. 1200 # each).

(4) A 5 psi minimum automatic (2-way) pressure relief valve for air transport. (Pressure differential between the cases not to be more than 8 psi at 50,000 feet altitude.)

(5) A manual pressure relief valve to facilitate opening the case. This valve may be incorporated as part of item (4).

(6) Humidity indicator to accommodate method II D pack per MIL-P-116 to minimize frequency of equipment inspections.

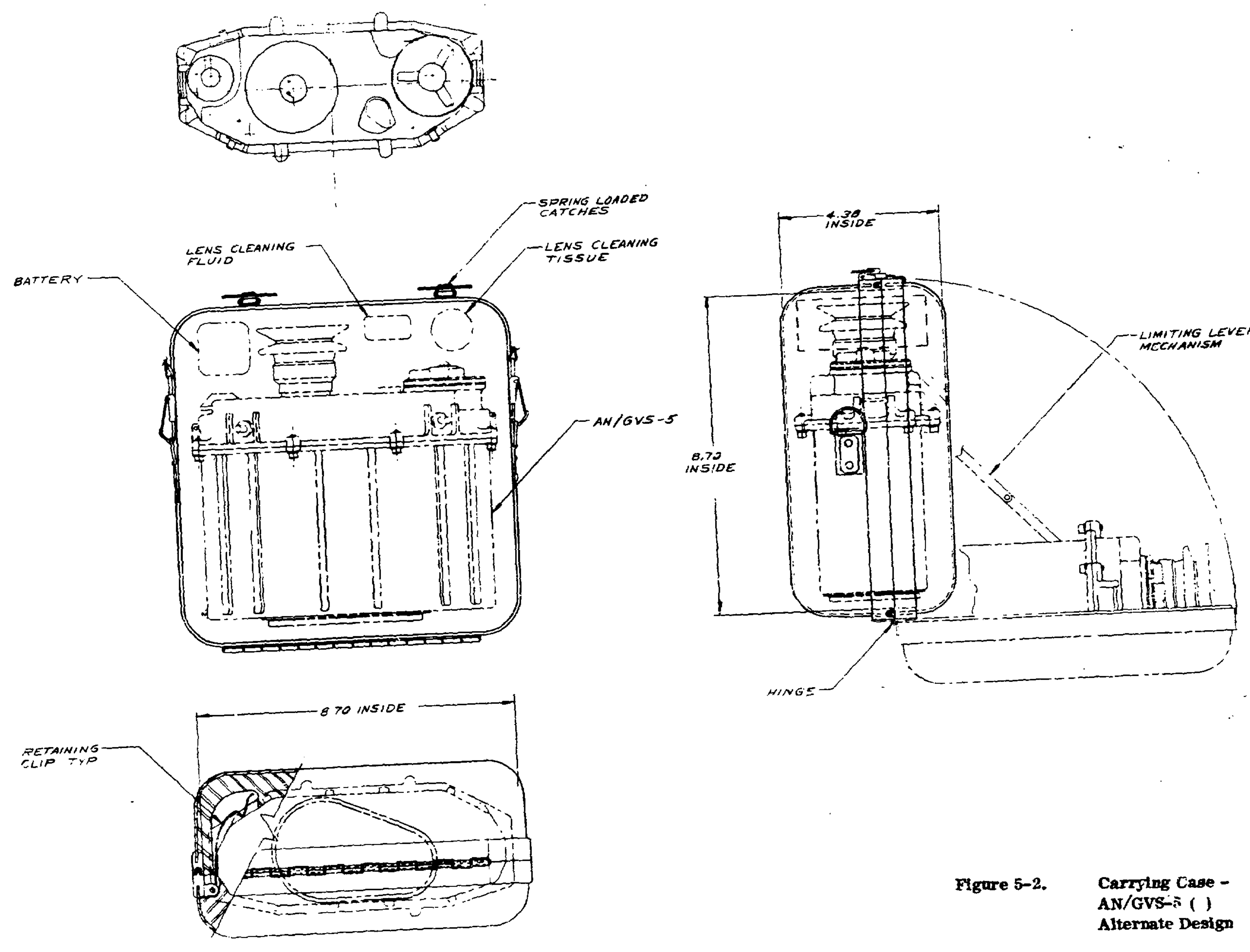


Figure 5-2. Carrying Case - AN/GVS-5 ( ) Alternate Design

NOTES:

1. DESIGN CRITERIA:
   THIS CASE SHALL CONFORM TO THE REQUIREMENT OF RDD-STD-2 AND SPECIFIED ENVIROMENTAL CONDITIONS:
   TEMPERATURE: -70°F TO +160°F.
   ALTITUDE: GROUND LEVEL TO 50,000 FEET.
   SHOCK: MIL-STD-810 METHOD 516 PROC II (INCLUDES 48 INCH DROP TEST). MAX INTERNAL EQUIPMENT RESPONCE 75 G'S (HH..R)
   IMMERSION: MIL-STD-810B METHOD 512 (3 FEET OF WATER FOR 2 HRS MIN.)
   VIBRATION: MIL-STD-810B METHOD 514 PROC II PART 2.
2. MATERIAL: THIS CASE WILL BE FABRICATED USING A PLASTIC AND/OR ALUMINUM MATERIAL CONFORMING TO THE REQUIREMENTS OF RDD-STD-2.
3. OUTLINE OF UPPER AND LOWER SHELLS OF THIS CASE MAY BE OPTIONAL BUT MUST PROVIDE RUB RAILS OR EQUIVLENT TO PROTECT THE CORNERS, CATCHES, HANDLES, HUMIDITY INDICATOR AND PRESSURE RELIEF VALVE DURING HANDLING AND DROP.
4. FINISH: COLOR CHIP NO. 34087, OLIVE DRAB GREEN, OF FED-STD-595.
5. MARK AS SHOWN WITH STANDARD GOTHIC LETTERS SIZED IN PROPORTION TO THE SIZE OF THE CASE, UNLESS SPECIFIED, USING WHITE MARKING INK, COLOR CHIP NO. 37875 OF FED-STD-595, PER TT-I-558. STANDARD LABELS MEETING THE REQUIREMENTS OF MIL-M-13231 & MIL-STD-130 ARE ACCEPTABLE.
6. GUIDES-NECESSARY GUIDES SHALL BE PROVIDED FOR ALIGNMENT OF TOP AND BOTTOM SECTIONS, OF CASE, AND ASSURE MIMINUM SHIFTING OF THE TWO SECTIONS AS A RESULT OF ROUGH HANDLING. GUIDES MAY BE AN INTEGRAL PART OF THE CLOSURE.
7. PREPARATION FOR DELIVERY:
   PACKING - LEVEL C
   CASES SHALL BE INDIVIDUALLY PACKED TO PROTECT AGAINST DAMAGE. CONTAINERS AND PACKING SHALL COMPLY WITH THE UNIFORM FREIGHT CLASSIFICATION RULES AND NATIONAL MOTOR FREIGHT CLASSIFICATION RULES AS APPLICABLE.

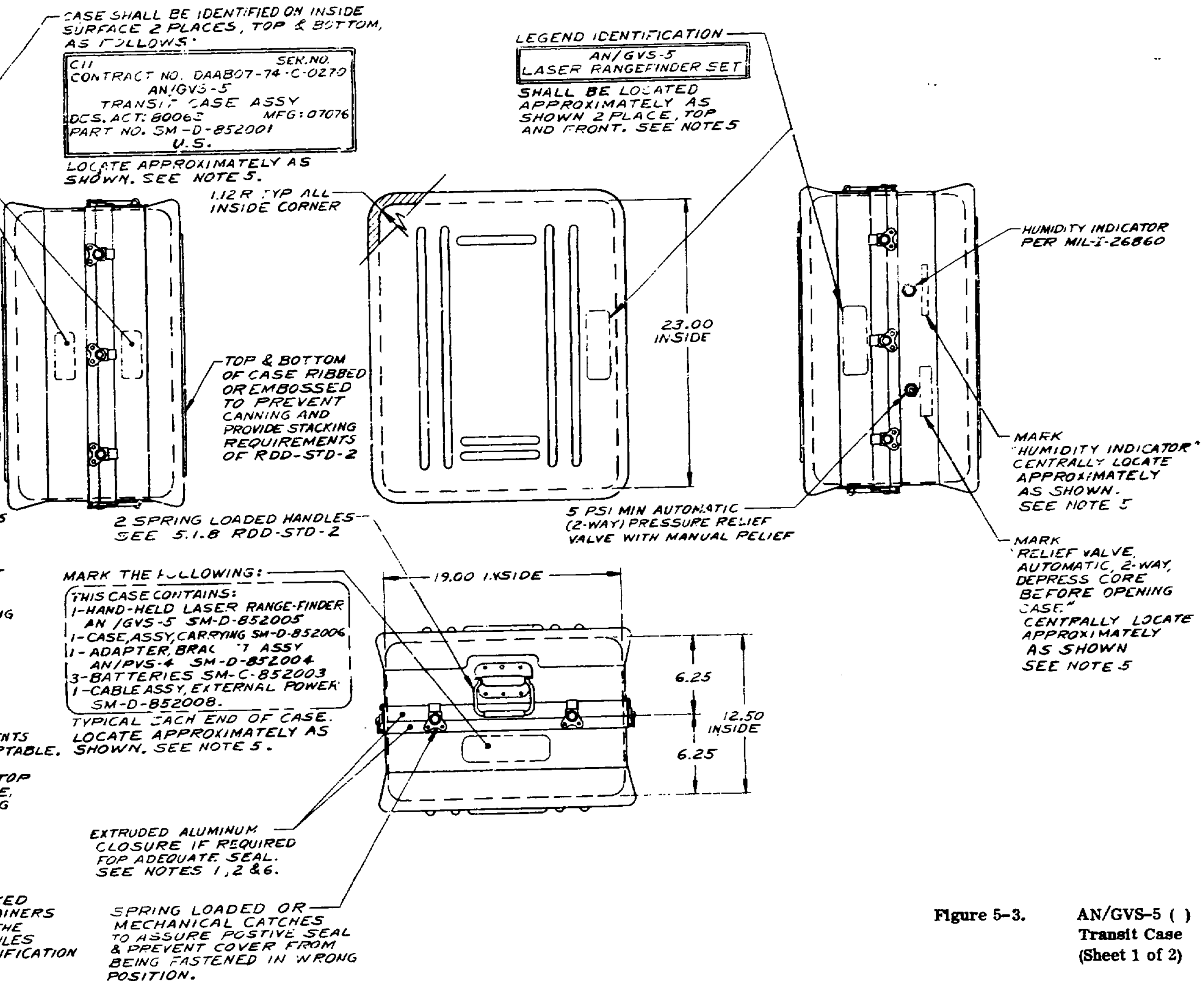
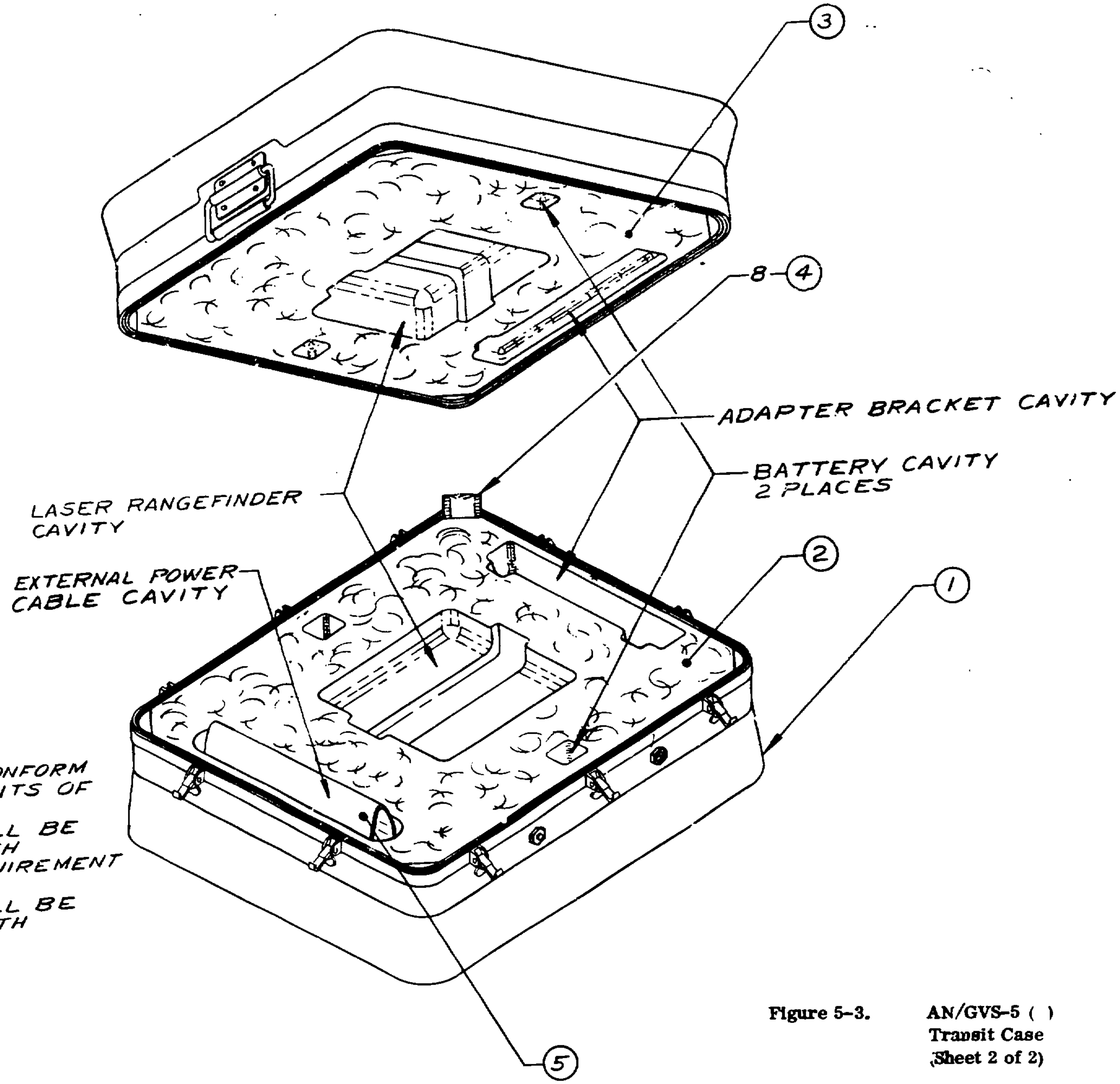


Figure 5-3. AN/GVS-5 ( ) Transit Case (Sheet 1 of 2)



NOTES:
1. THIS CASE SHALL CONFORM TO THE REQUIREMENTS OF RDD-STD-2.
2. WORKMANSHIP SHALL BE IN ACCORDANCE WITH MIL-STD-454 REQUIREMENT 9.
3. IDENTIFICATION SHALL BE IN ACCORDANCE WITH MIL-STD-130.

Figure 5-3. AN/GVS-5 ( ) Transit Case (Sheet 2 of 2)

Interior: (1) Support cushions designed to meet the environmental conditions specified in Paragraph 5.2.1:

(a) Cut-outs/slots will be provided to contain desiccant and equipment specified in Paragraph 5.2.1. Hand holes will be provided where necessary to accommodate easy removal of equipment.

(2) Desiccant will be provided for the protection of the items and cushioning during transportation and storage.

5.3 ADAPTER BRACKETS

Two adapter bracket configurations are to be furnished, enabling the AN/GVS-5 ( ) to be used with 1) the AN/TAS-2 night sight and 2) the AN/PVS-4 night observation device. Figures 5-4 and 5-5, respectively, provide detailed specifications of these brackets. Both adapter brackets are fabricated of cast aluminum with female "V" adapters and captive thumb screws for AN/GVS-5 ( ) attachment at the right end (as seen from the eyepiece). Matching features to suit the geometry of the interfacing equipment are placed at the left end and center of the adapter bracket castings.

Functionally, the "V" groove concept provides a quick, convenient and precise means of attaching the various system components together. The AN/GVS-5 ( ) and AN/PVS-4 each have a stainless steel male "V" which registers positively in a matching female "V" in the adapter to provide optical alignment. A captive thumb screw, with a 1/4-20 UNC-2A thread, is used as the fastener. Only the AN/TAS-2 accessory bracket interface differs from this geometry, in that it employs a vertical guide-rail coupling scheme for the NOD as described in section 5.3.1.

The aluminum casting alloys used for these parts, described in detail later on, have been selected for their suitability as to the anticipated production process, strength and stability requirements, ease of fabrication, and material cost. Stainless steel adapter parts will be hardened to increase their damage resistance. All stainless steel parts, including hardware, will be blackened.

The accessory brackets have been conservatively designed, and provide generous safety factors at the 10 g design loading. The following table summarizes the results of the stress analysis performed on the accessory bracket, and discussed in section 3.2, for the case of a cantilever beam vertically loaded, and torsionally loaded about a horizontal axis.

Equipment Combination	Loading Mode	Maximum Calculated Stress at 10 g (psi)
AN/GVS-5( ) with AN/PVS-4 and Tripod	Vertical Bending Horizontal Torsion	2.52×10^3 1.13×10^3
AN/GVS-5( ) with AN/TAS-2	Vertical Bending Horizontal Torsion	2.26×10^3 1.22×10^3

These are sufficiently below the precision elastic limit of Fy = 12,000 psi to preclude long term yield.

Primary criteria in the accessory bracket casting design are: adequate strength to withstand the impact loadings of field use, and sufficient long-term dimensional stability to preserve boresight accuracy. The calculated stress values using a 10 g impact loading indicate an approximate minimum safety factor of 3 to 1 based on the yield strength of SC84B aluminum die casting alloy.

The adapter bracket components will be completely pre-machined and finished before assembly. On the AN/TAS-2 adapter, alignment fixtures will be used during assembly to position the hardened female "V" brackets and to posit[illegible] the front guide rail during drilling and pinning

5.3.1 AN/TAS-2 Adapter

As indicated above, the AN/GVS-5 ( ) will be cantilever-mounted to the right side of the night sight with an accessory bracket of RCA design. With or without the AN/GVS-5( ) attached to its right end, this bracket slides down over two vertical rails on the night sights to a stop position and is clamped in accurate optical alignment by tightening a single thumb-screw-actuated gib. The accessory bracket casting is of 356-T6 aluminum alloy, machined to match the AN/GVS-5 ( ) female "V" groove adapter, the movable gib/thumbscrew components, and an opposing, front guide plate. This alloy, 356-T6 is used because of 1) the low quantity requirement and thus the probable use of a sand, investment, or permanent mold casting, and 2) its long term stability capability. Stability can readily be achieved by proper heat treatment and is important in this adapter because of small NOD reticle adjustment capability. Of the total

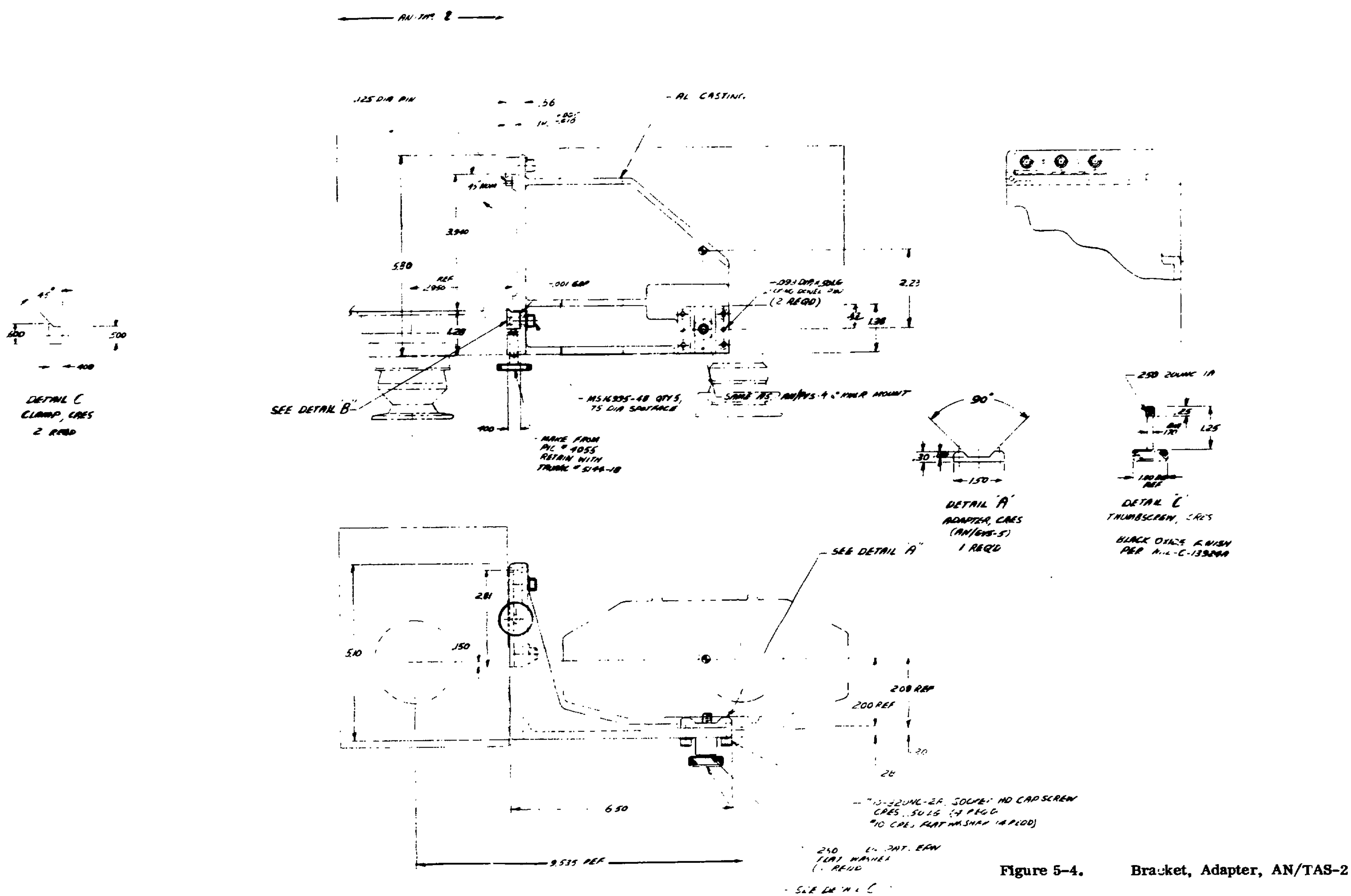


Figure 5-4. Bracket, Adapter, AN/TAS-2

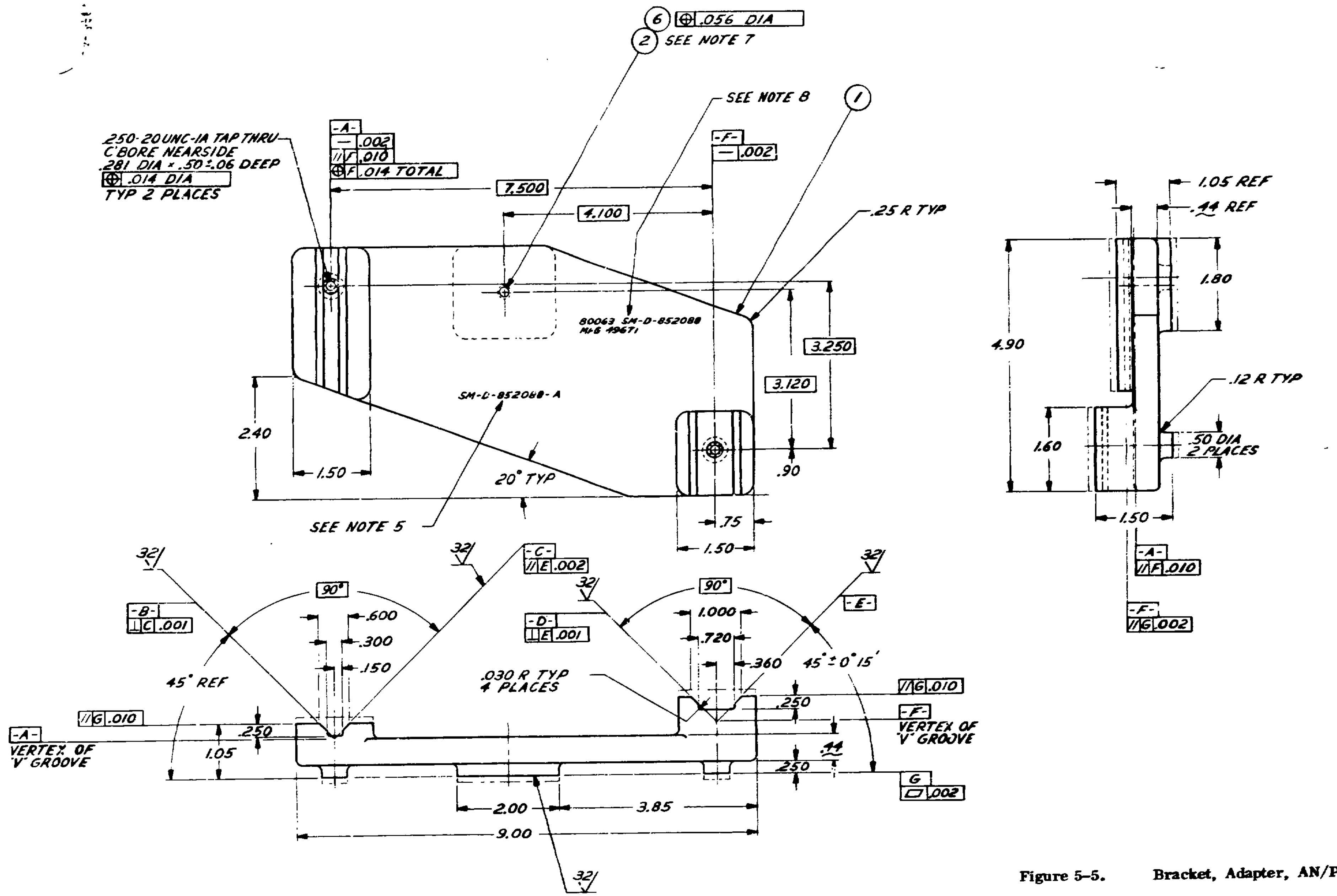


Figure 5-5. Bracket, Adapter, AN/PVS-4

range of ±3.5 mr available, ±2.5 mr is available for alignment of the NOD to the GVS-5/adapter. Thus long-term instability of the adapter could be significant.

5.3.2 AN/PVS-4 Adapter

As noted earlier, this accessory bracket is designed to physically join, as a system the AN/GVS-5( ) and an AN/PVS-4 individually-served night observation DEVICE (NOD). A machined boss on the bracket underside, with integral 1/4-20 UNC-2B thread, enables attachment of the bracket-coupled assembly to an azimuth-elevation head. At both ends of the accessory bracket, a captive thumbscrew with 1/4-20 UNC-2A thread clamps both the AN/GVS-5( ) and the NOD into the mating "V" grooves which are machined into the aluminum casting. The V-ways will be hardened to minimize wear. Hardened aluminum V-ways are used in this case because of the very large reticle adjustment capability of the PVS-4. This approach is considerably less expensive than that of separate steel V's. The design shown in Figure 5-5 will be modified to include cast-in bosses to be used as machining references. A version of the design will also be made to use essentially constant wall thickness under the V's to determine if this configuration can be die cast.

5.4 REMOTE POWER CABLE

5.4.1 Electrical Requirements Description

The remote power cable assembly will provide the interface connection between the HHLR and the vehicle power source. The cable assembly (shown in Figure 5-6) will contain the necessary filtering and power conditioning circuitry to suppress line transients and reduce ripple to acceptable levels. All circuitry will be contained in a module which will physically replace the regular system battery. The circuitry will aslo provide filtering to control EMI conducted radiation-emanating from the HHLR. The remote power cable assembly will provide a 2 ampere drive at a 20 volt output voltage level.

The vehicle power supply has three distinct operating modes:

Mode 1. Normal system with battery support. (Includes the combined generator-battery supply.)

Mode 2. Battery only.

Mode 3. Abnormal system without battery support. (Generator only without battery.)

In Mode 1, the steady state voltage limits are 26 to 30 volts, with peak to peak ripple not exceeding four volts. The frequency components of the ripple occur within a range 100 cycles to 20,000 cycles for fundamental frequencies, with harmonics up to 200,000 cycles. Transient voltages up to 40 volts and down to 15 volts are produced in this mode.

In Mode 2, the steady state voltage varies between 20 and 25 volts. No transients are produced in this mode since the generator is off the line, and the only voltage source is the battery.

In Mode 3, operating conditions are at their worst. Transients are produced in the absence of battery support which range from 10 volts up to 100 volts. The upper limit of the steady state voltage including a maximum peak to peak ripple of 10 volts, is 40 volts, the lower limit being 26 volts.

The ripple component of the power supply voltage developed by the remote cable circuitry assembly must not exceed one volt, peak to peak, under all operating conditions to preclude activation of the HHLR power supply under-voltage circuit.

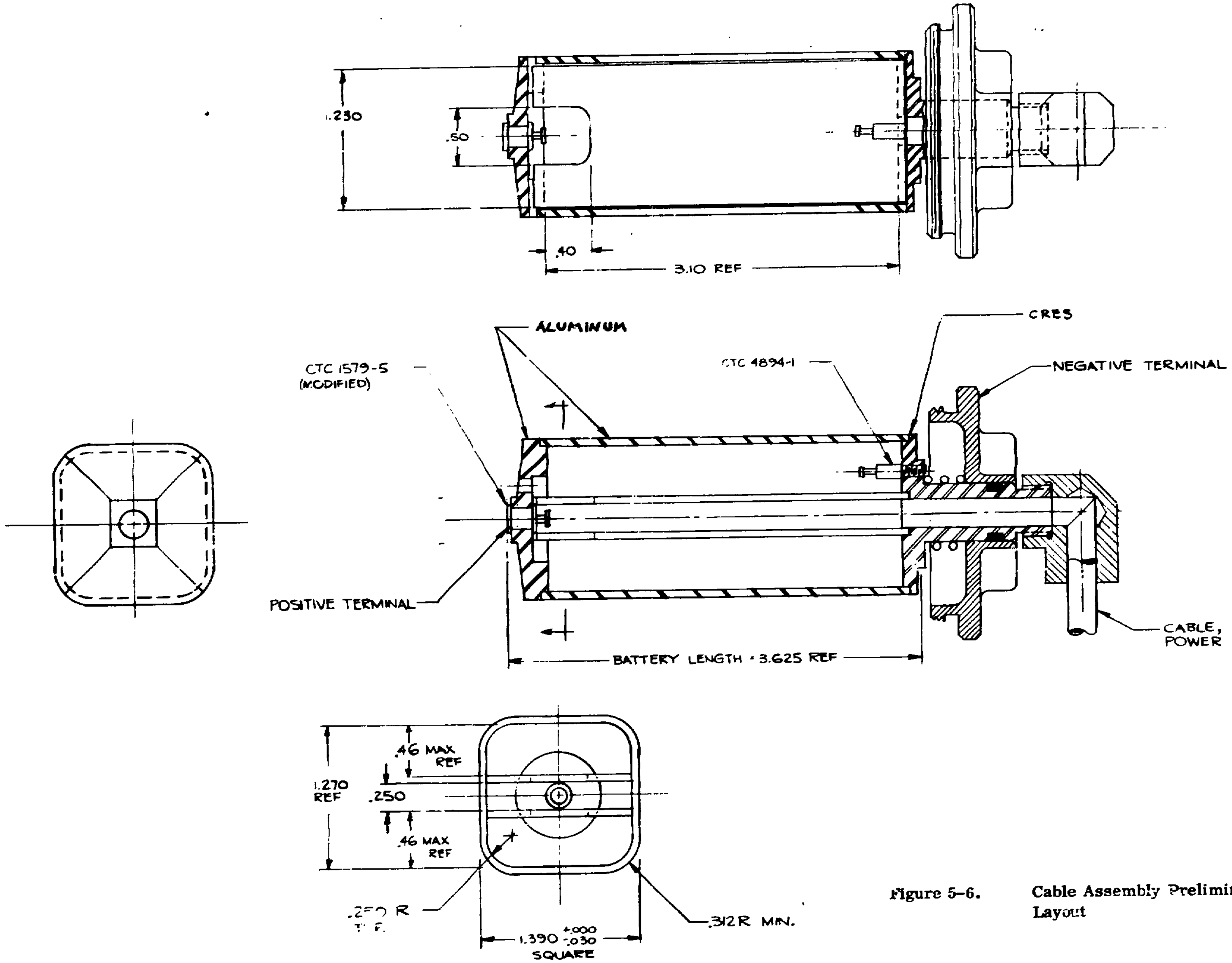


Figure 5-6. Cable Assembly Preliminary Layout

The regulator is a dissipative series configuration utilizing a high gain, high voltage Darlington arrangement (Figure 5-7). Variable resistor R9 is used to set the output voltage to 20V and to take up the variation in parameters due to purchase tolerances. Q_3 is five transistor array in a DIP package connected in a differential amplifier configuration and serves as a reference amplifier. Q_2 is a high voltage driver amplifier which controls the base drive to the Darlington. Diode CR-3 is a 43 volt zener which clamps the base of Q_1 to 48 volts to protect Q_1 from transient inputs. Diode CR-2 protects Q_1 from negative going transients to the 15 volt level when the HHLR power supply capacitors are charged to +20 volts.

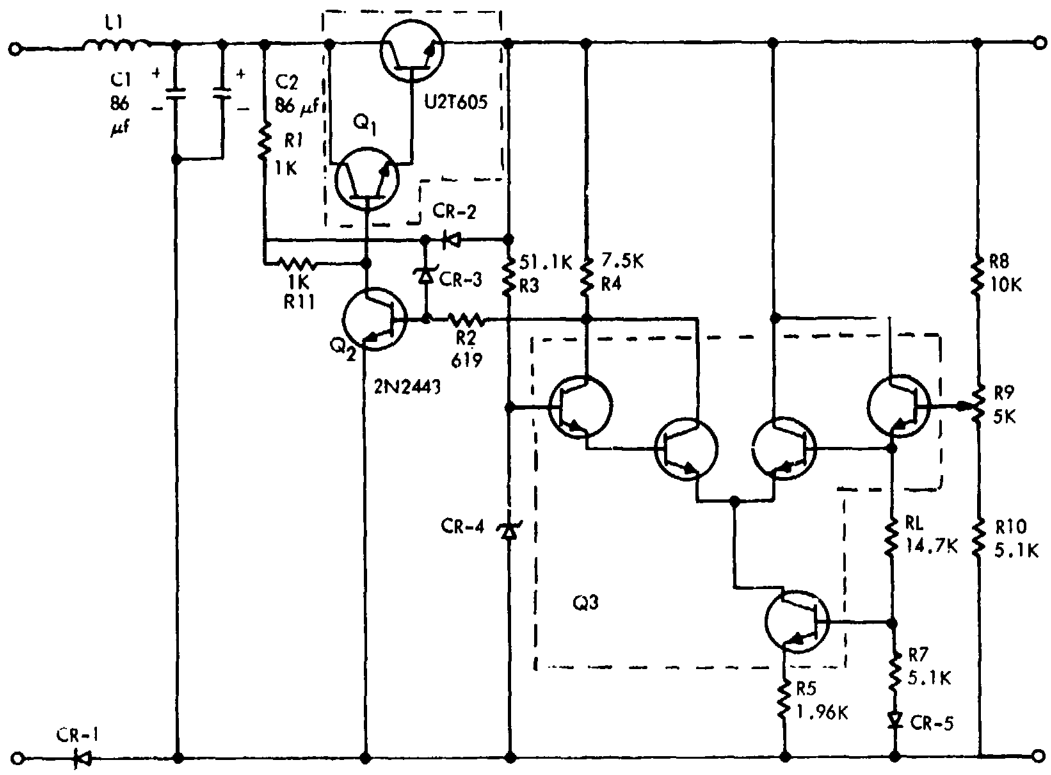


Figure 5-7. Regulator Schematic

SECTION 2

BASIC DESIGN APPROACH

2.1 DESIGN CONFIGURATION

The AZ-EL Head, shown in Figures 2-1 and 2-2, interfaces the Laser Rangefinder (HHLR) and the Night Vision Device (NVD) with the Tripod Assembly, Shelf Mount, and Universal Tripod (drawing numbers 10540178, 10541103, and 6675-641-3572 respectively). It is configured to: (1) mount the HHLR alone, or (2) the HHLR and NVD together. When mounted alone, the HHLR is positioned at the top of the elevation gimbal. In this position its center of gravity is nominally along the azimuth axis to minimize unbalance torques. When mounted with the NVD, the HHLR is mounted to a removable adapter located on the right side of the AZ-EL Head while the NVD mounts directly to the gimbal on the left side of the AZ-EL Head. The combined center of gravity of the HHLR, its adapter, and the NVD is nominally at the intersection of the azimuth and elevation axes of the AZ-EL Head - again, to minimize unbalance. All interfaces to the AZ-EL Head and the adapter are via mating male and female 'V's' with a single thumbscrew used as the fastener in each case.

Azimuth and elevation positions are manually controlled by knobs on the right rear and right front of the AZ-EL Head respectively. Angular position is read directly from illuminated and magnified scales. An illuminated bubble level is provided as a basic reference for elevation angle. Power for the illumination is provided by two 'D' cells and is controlled by an ON-OFF switch and a brightness control.

The Tripod Assembly used with the AZ-EL Head has been modified to increase its base circle from 15 to 20.8 inches, when non-extended. This provides greater stability of the assembly, particularly when only the NVD is mounted to the Head during installation.

2.1.1 Mechanical Design

Basically, the AZ-EL Head is composed of five elements:

(1) Adapter Mount
(2) Azimuth Drive and Readout
(3) Azimuth Gimbal
(4) Elevation Drive and Readout
(5) Elevation Gimbal

The Adapter Mount has lost its identity and has become an integral part of the AZ-EL Head. Those portions of the Adapter Mount retained include the Base Assembly, which interfaces with the Tripod and Shelf Mount, the Leveling Screw Assemblies, the body and its mating shaft, the azimuth clutches, and the azimuth drive gear set. Modifications to the tripod, leveling screw, and leveling screw spring are discussed in sections 2.1.4 and 2.2. Only minor modifications are made to the azimuth drive, e.g., increasing the diameter of the drive gear to enhance accessibility to the azimuth knob.

For azimuth angle readout a direct reading cursor is used in place of the imaging system formerly used with the Adapter Mount. A five and a half inch scale in conjunction with a vernier and a simple, illuminated magnifier, enables azimuth bearing to be read to 1 MIL. For leveling, an illuminated circular level with a level capability of ± 0.5 MIL is provided on the azimuth gimbal. The limit stop on the azimuth shaft of the Adapter Mount has been deleted to allow continuous rotation in azimuth. New parts which interface with the original base assembly include the azimuth cursor, the 'new' azimuth gimbal, and a shaft sealing cover.

The 'new' elevation drive assembly is a completely sealed unit containing, in addition to the drive, two internal readout scales and all of the elements of the illumination system which comprises: (1) the batteries and their container, (2) the bulb, (3) the ON/OFF switch, (4) the dimmer potentiometer, and (5) the fibre optics bundle used to transmit the light from the bulb. The elevation drive consists of a 64 tooth spur gear and a spring gear and a spring loaded, single-lead worm gear. Thus, one revolution of the input knob provides 100 MILS of rotation. A simple circular scale provides readout resolution of 1 MIL. A second scale, graduated from plus to minus 500 MIL, in 100 MIL increments, completes the elevation readout. Each scale is illuminated and is directly read through a window.

The elevation drive knob is located on the right side of the Head and its axis of rotation is parallel to the elevation axis. This orientation is preferred from a human engineering standpoint and is accomplished via an intermediate right angle drive on the input shaft. A large diameter knob is used to provide ease of gripping and ease of turning.

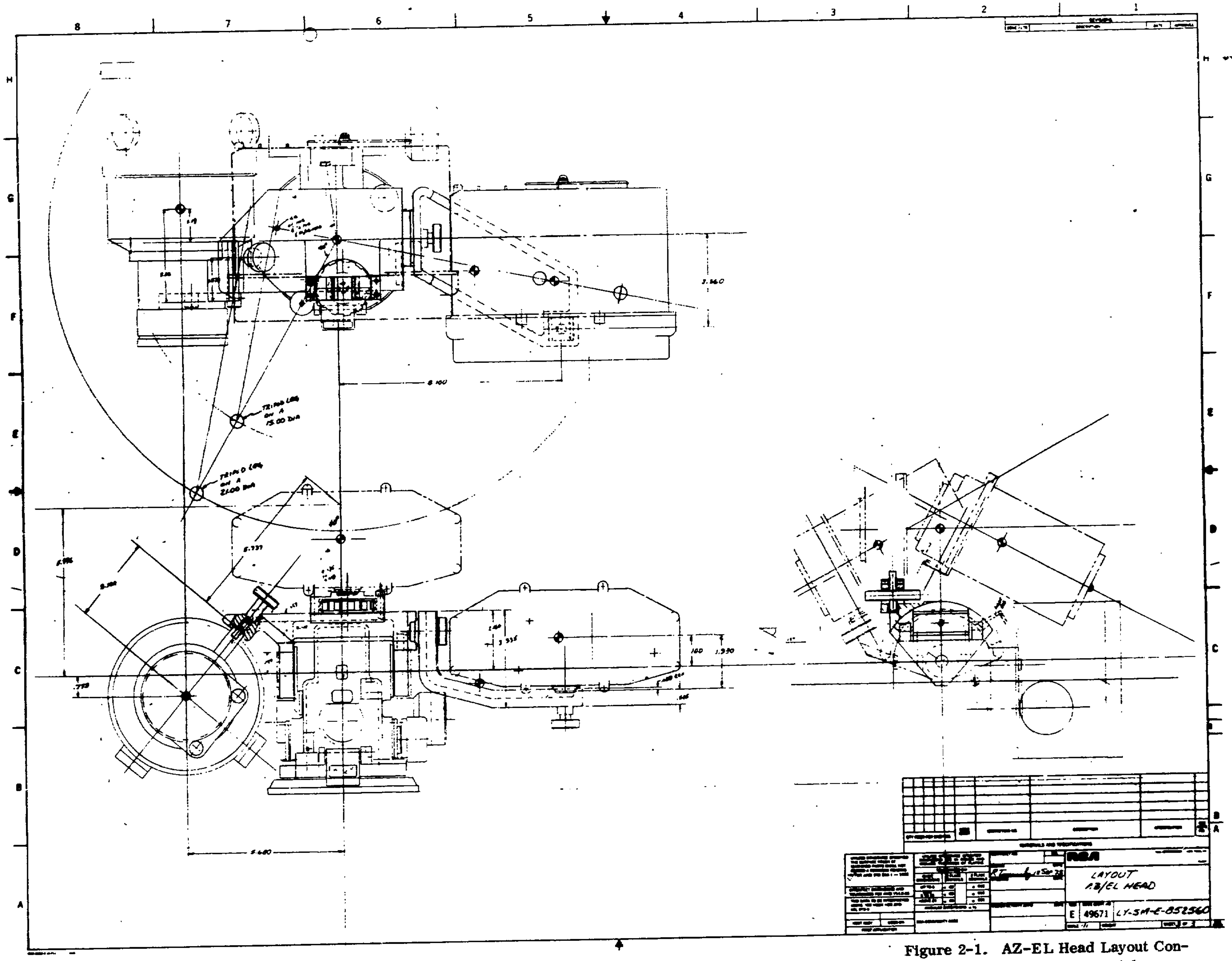


Figure 2-1. AZ-EL Head Layout Configuration - Part 1

Ball bearings are used on the spur gear shaft and the input shaft to optimize performance, to provide the positional tolerances necessary and to maintain accuracies. The elevation drive assembly is sealed to assure performance with the specified environments. The elevation scales, the azimuth scale, and the leveling vial are illuminated by a single bulb whose output is modified by a red filter. Four non-coherent fiber optic bundles channel the light from the bulb to the required areas of illumination. Power for the 25 MSCP, 0.190 amp bulb is provided by two "D" cell batteries located in a case mounted on the housing. A dimmer potentiometer and momentary contact switch are provided for control. All wiring is internal to the elevation drive housing.

2.1.2 Azimuth Drive

As originally in the adapter mount, the azimuth drive comprises a single reduction assembly whose output pinion meshes with a large drive gear. Spring loaded clutch discs allow slewing as well as controlled drive. Most of this original design is used intact. The single reduction assembly, clutches, and the shaft and sleeve bearing have all been retained. The large fine-tooth gear (drawing number 10541140) has been increased from 344 teeth and 3.604 O.D. to 419 teeth and 4.385 O.D. It was necessary to enlarge this gear to provide adequate hand clearance for the azimuth drive knob which is located behind the elevation knob as shown in Figure 2-4. A wooden model of the AZ-EL Head was made to determine the optimum location for the knob. However, the choices were limited by the configuration of the elevation drive housing and the large diameter of the azimuth cursor. To make the azimuth knob easier to turn while the operator is wearing arctic mittens, the diameter and height of the knob have been increased.

Because the body of the azimuth drive is not sealed, a cover with an "0" ring seal was designed to seal the hollow azimuth bearing shaft (drawing number 10541132). In addition a preformed "0" ring provides a seal between the gear box housing and the azimuth mounting plate. The azimuth mounting plate replaces the former plate (drawing number 10541125). As discussed below, the batteries are now located on the gear box housing and all wiring is direct. This arrangement allows the deletion of the quick disconnect assembly and ancillary wiring used with the adapter mount.

2.1.2.1 Azimuth Angle Readout

Azimuth angles are read from a 5.5 inch diameter graduated ring using a vernier. The ring contains sixty-four numerals with nine graduations between numerals. A magnifying lens enables the operator to read the vernier to one MIL. Both the vernier and the graduated ring are made from black anodized aluminum. When the characters and graduations are engraved through the black anodize, the bright aluminum substrate is exposed. A clear epoxy overcoat after engraving maintains the high contrast between the bright aluminum substrate and the black anodize.

The azimuth ring and vernier are viewed through a 2x magnifying lens located in the azimuth readout assembly. Illumination for the readout is provided by a branch of the fiber optic illumination system. To uniformly illuminate both the azimuth ring and the vernier, the conical light egressing from the fiber optic bundle must be spread and diffused. This is accomplished by use of a fixed, one piece azimuth light diffuser as shown in Figure 2-3. This diffuser receives light from the fibre optics bundles and then both diffuses this light as well as reflects it onto the azimuth vernier and scale.

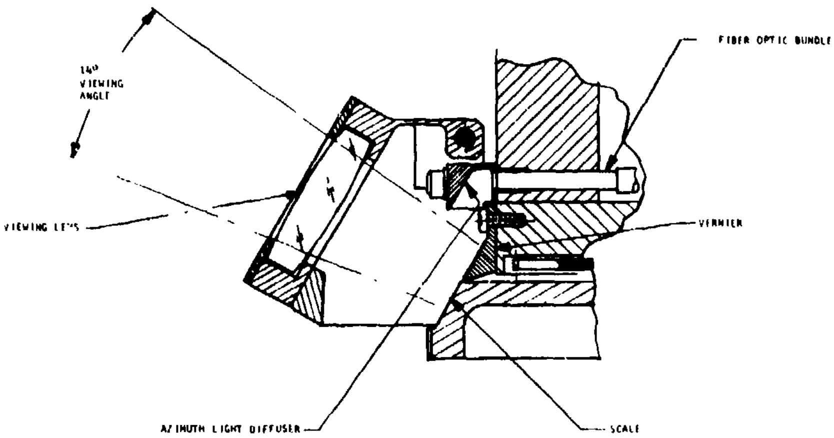


Figure 2-3. Azimuth Angle Viewer

Since the azimuth readout, azimuth ring, and azimuth vernier are not sealed, provisions have been made for easy access to the inside surface of the magnifying lens for cleaning. The azimuth readout assembly containing the magnifying lens is hinged at its rear edge. This allows the forward edge of the assembly to be rotated upwards, thus exposing the inside surface of the lens. A spring-loaded ball detent secures the assembly in the down position.

2.1.3 Elevation Drive

To obtain the required positioning accuracy and holding capability, a 64 tooth spur gear and a single-lead worm gear are used to drive the elevation gimbal. Several methods for meeting angular transmission requirements consistent with overall requirements were considered.

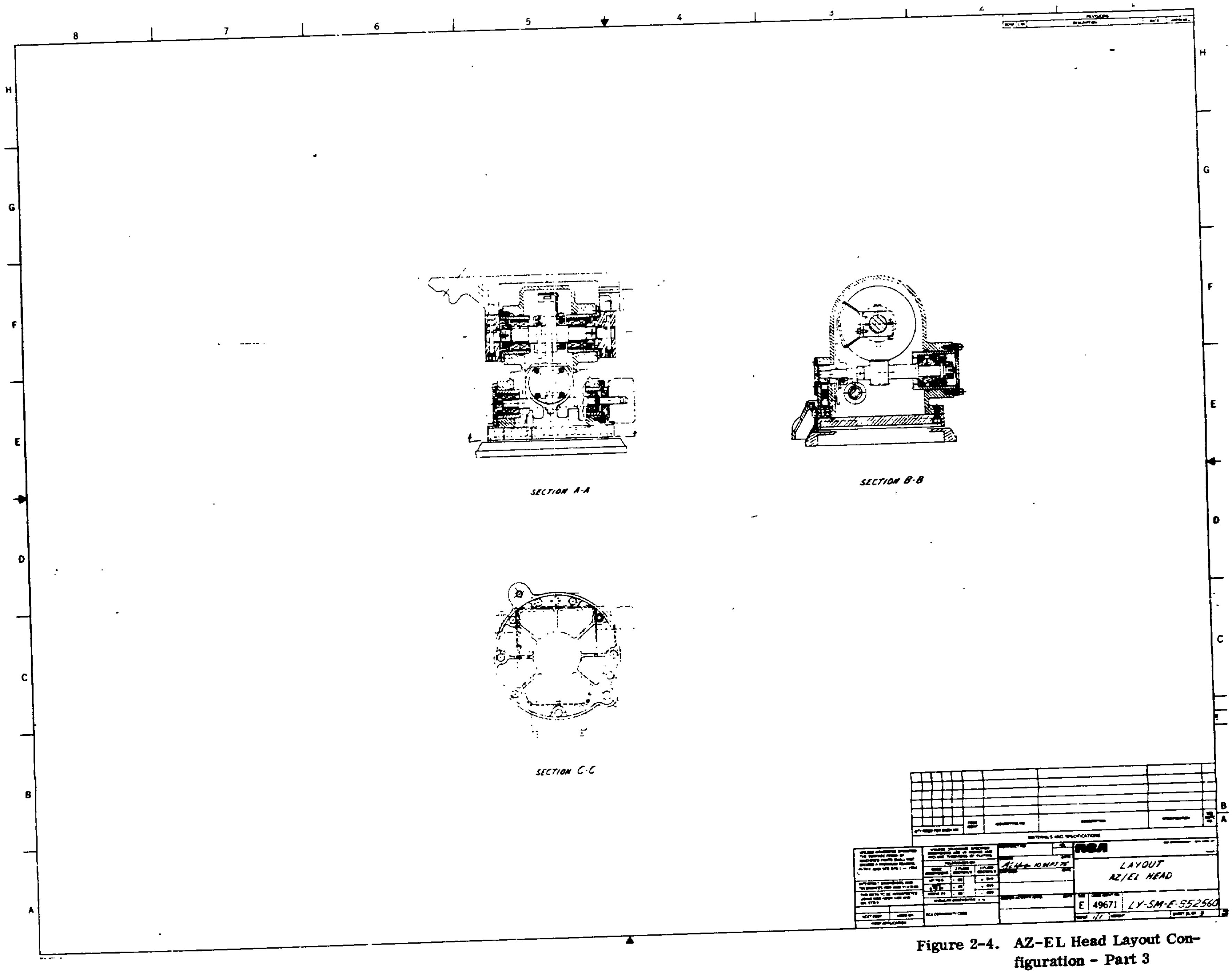


Figure 2-4. AZ-EL Head Layout Configuration - Part 3

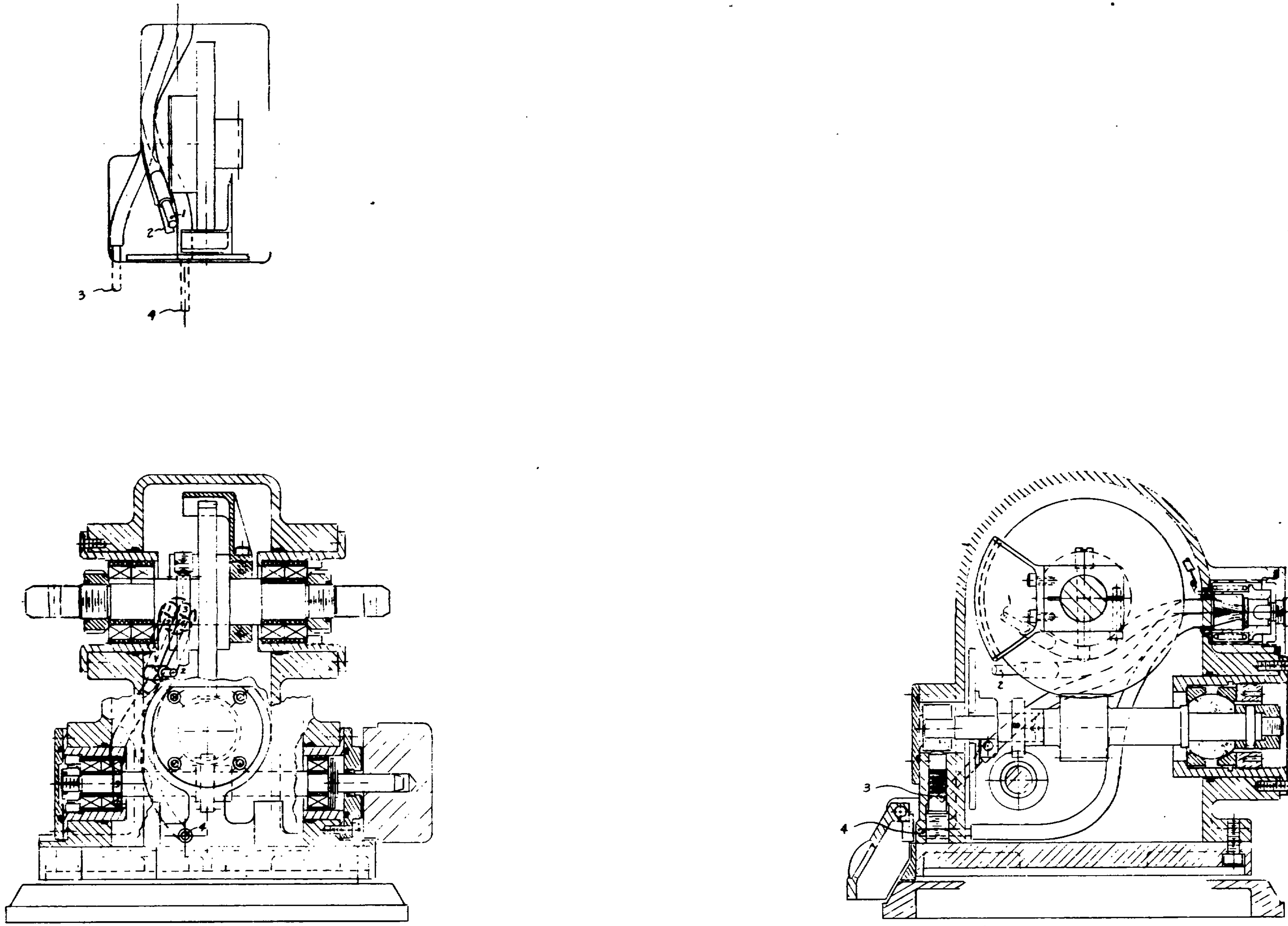


Figure 2-5. AZ-EL Head Layout Configuration - Part 4

To maintain position while subject to a 35 inch-pound external torque load, a worm and gear drive was established as the baseline. Three different worm drives were investigated. Of the three types (see Analysis, Buckingham A Associates Inc., Appendix 8.1), the spur gear and cylindrical worm were selected as the most advantageous for the AZ-EL Head application.

Four design variations were analyzed and are discussed in detail in section 3.1.3 3.1.2. These variations are:

(1) Fixed center-to-center design with both worm and gear shafts supported by ball bearings.

(2) Same as (1) but with variable center-to-center distance via eccentrics on the gear axis.

(3) Same as (1) but with an external spring used to load the gear against the worm and thus remove backlash.

(4) The gear axis same as (1) but the worm spring-loaded against the gear to remove backlash.

Design variation (4) is used in the AZ-EL Head since the analysis showed this approach to have lowest overall error, 1.19 mr, and to have only 0.11 mr of effective backlash. The latter is in the form of axial play in the worm shaft. A prime consideration in this choice was the desire to minimize backlash for effective use of the equipment in the field.

The physical configuration of this design is shown in Figure 2-5. It consists of three shafts and two gear meshes. The three shafts are: (1) the input shaft, (2) the worm drive shaft, and (3) the elevation shaft. A 1:1 crossed helical gear drive is used between shafts (1) and (2); a 1:64 single reduction worm gear drive is used between shafts (2) and (3). The elevation shaft is supported by and rotates in two pairs of back-to-back preloaded deep groove ball bearings. The inner races of the bearings are locked to the shaft by a bearing nut. The outer races of one pair are locked to a steel sleeve by a locking ring. The outer races of the second pair of bearings are free to float axially in a steel sleeve. By this means, all radial and axial play is removed and bi-directional thrust loads are taken by one bearing pair.

The ball bearings used in the elevation gear box are mounted in 17-4 PH stainless steel liners. The function of the liners is to prevent bearing bind resulting from differential shrinking between the aluminum housing and the stainless steel bearings at low temperature. These temperature effects are discussed in section 3.3.1.1. In addition, the sleeves provide a harder surface than the casting and therefore will ease the assembly of close fitting parts. Large ID bearings (0.50 inches) were selected to allow a shaft with good torsional stiffness. The spur gear is bolted with four screws to a locating flange on the shaft. In addition to bolting, the gear is pinned with a tapered pin which is positively retained with a locking set screw. This tapered pin technique permits easy removal of the pin without backup support and use of an arbor press.

The worm shaft is supported by and rotates in a phosphor bronze bearing at each end. At one end, the phosphor bronze bearing has a truncated spherical outer surface and is supported so that the shaft and bearing are free to rotate about the center of the sphere. At the other end, the phosphor bronze bearing is free to ride in a slot so that it can move towards or away from the elevation shaft. A spring load is applied to the O.D. of this phosphor bronze bearing in the direction of the elevation shaft. Thus an essentially constant force is applied to load the worm against the gear so as to remove backlash due to tolerances and temperature effects. The details of this configuration are discussed below.

The worm is cut into the shaft to preclude mounting errors. The worm shaft mounting is unique in that the technique is such that it is both self-aligning and temperature compensated. One end of the worm shaft is axially captivated by the spherical bearing and an adjustable sleeve. The thrust surfaces are the two flat faces of the spherical bearing, a shoulder on the shaft, and a shoulder on the sleeve. The sleeve is adjusted at assembly to limit the axial play of the spherical bearing to $0.00015 \begin{smallmatrix} +0.00015 \\ -0.00000 \end{smallmatrix}$ inches and then pinned to the shaft to assure permanent alignment. The spherical bearing, in turn, is retained by two conical seats and an adjustable retaining ring. All play is removed between the spherical bearing and the conical seats by adjusting the retaining ring until a specified torque on the shaft produces rotation. A nylon pellet in the retaining ring prevents it from becoming loose after assembly thus the shaft rotates in the bore of the spherical bearing and can pivot about the center of the sphere. As discussed in detail in section 3.3.1.2, this bearing arrangement is temperature compensated so that once axial play is set it does not change with temperature.

Temperature compensation is achieved by using materials with different thermal coefficients of expansion. The material for the worm gear and worm shaft is CRES 17-4 PH which was selected for its hardness and wear characteristics. Phosphor bronze was chosen for the spherical bearing material because of its bearing properties. In order to maintain the 0.00015 gap between the spherical bearing and the thrust surfaces on the shaft and the adjustable sleeve over the temperature range, the adjustable sleeve is made of chrome plated invar.

This configuration provides zero differential expansion of the distance between the thrust surfaces on the shaft and the sleeve and the width across the spherical bearing. Type 303 stainless steel is used for both the conical seats and the outer sleeve since the thermal coefficients of expansion of 303 and phosphor bronze are almost identical.

Radial play of the shaft in the phosphor bronze bearing will vary as a function of temperature. However, motion in the direction of the elevation shaft is controlled by the spring, and transmission error is very insensitive to motion perpendicular to the elevation shaft as shown in section 3.1.2.

To provide the spring loading at the opposite end of the worm shaft, a phosphor bronze bearing is located within a machined slot in the casting. The dimensions of the slot are such that the bearing will slide in a vertical direction but horizontal motion is restricted. A phosphor bronze-bearing was selected because its low coefficient of friction allows motion freely in the slot and because its coefficient of thermal expansion is identical to that of the gear box casting thereby precluding temperature problems. The spring force is applied to the bearing in a vertical direction through a small piston. The top surface of the piston bears against the bronze bearing and is dome shaped to allow angular misalignment of the bearing. Travel of the piston in the direction of the spring is controlled to limit the separation of the worm gear and spur gear during momentary overloads.

Three ball bearings are used to mount the input shaft. A pair of back-to-back preloaded deep groove ball bearings is used on one end of the shaft to eliminate all axial and radial play and to perform as a bidirectional thrust bearing. A bearing nut clamps both bearing inner races against a shoulder on the shaft and a retaining ring locks the outer race to its sleeve. The other end of the helical gear shaft is supported by a single low-radial play deep groove ball bearing. The outer race of this bearing is not locked to allow axial movement resulting from differential expansion between the stainless steel shaft and the aluminum housing. The bearing liners of the drive shaft serve a second function. Because of the cumulative tolerances resulting from the many separate parts used to spring load the worm gear, the drive shaft is made adjustable relative to the worm shaft. By boring the bearing sleeve slightly off axis, the bearing sleeve becomes an eccentric. Eight mounting screws are used on the eccentric flange to provide 45° increments of rotation. A scribe mark locates the high point of each eccentric. By simultaneously rotating the eccentrics at each end of the drive shaft, backlash is removed from the pair of helical gears to produce a positive feel in the elevation knob. Note that the backlash between the helical gears does not produce a positional error. By using right hand helical gears, a clockwise rotation of the elevation knob produces a downward rotation of the LOS.

The expense and complexity of the use of the crossed helical gears and an additional shaft is considered justified from the human engineering standpoint. The reason is that if the right angle drive were not used and if the elevation knob were mounted directly on the worm shaft, the elevation knob would be located directly in front of the operator. This location would not only be awkward for the operator but would also partially block the azimuth readout.

In order to determine the necessary spring load for the worm gear, the separating force between the worm and spur gear was calculated, as shown in section 3.1.1, for the assumed worst case (35 in-lbs) torque load. Next, a spring was chosen whose force slightly exceeds the resultant bearing force. This spring force produces the same load condition on the drive knob as if there were a constant 35 in-lbs (worst case) load being applied to the gimbal. Assuming a starting efficiency for the worm gear set of 20 percent and a starting efficiency for the helical gear pair of 70 percent, the starting torque for the knob is 3.9 in-lbs. The torque required to drive the gimbal drops significantly after overcoming the starting friction. Assuming running efficiencies of 30 percent for the worm and spur gear combination and 90 percent for the helical pair, the running torque for the elevation knob drops to 2.0 in-lbs. Worm gear and spur gear efficiency does not lend itself to precise calculation. Therefore, the 20 percent starting efficiency and the 30 percent running efficiencies are considered very conservative.

All gears are cut or ground from stainless steel for optimum strength and wear characteristics and then finished with an Electrofilm lubricant. Electrofilm is a solid film lubricant consisting of lubricating pigments and molybdenum disulphide (MoS_2) in a thermosetting resin binder. The Electrofilm provides permanent lubrication that will also improve drive efficiencies. Although point contact is used in both gear meshes, the design is such as to assure adequate life. This is discussed in section 3.1.1.

2.1.3.1 Elevation Gimbal

As seen in Figure 2-4, the gimbal is mounted to the elevation gimbal shaft by the use of two mounting blocks which are pinned to the shaft using tapered pins as described above. During pinning, the blocks are aligned and positioned with the aid of a fixture. The gimbal is hard-bolted to one of those blocks and is attached to the other block by a spring loaded fastener. This arrangement allows torque to be transmitted from the gimbal to both ends of the elevation shaft while allowing sliding to occur between the gimbal and the shaft during temperature excursions. The gimbal has three female V's machined in or mounted to it. These accept the HHLR, NVD, and an adapter for the HHLR. In each case, a single captive thumbscrew is used as the fastener. A cast aluminum adapter, shown in Figure 2-2, is used to mount the HHLR on the side of the AZ-EL Head when it is used with the NVD. This provides for a balanced, low-profile assembly.

2.1.3.2 Elevation Angle Readout

Elevation angles are read through two sealed viewing windows. Two elevation scales are located inside the sealed housing. The scale mounted on the spur gear shaft has ten numerals, and is graduated from zero to plus five and from zero to minus five. Each numeral represents a displacement of 100 MILs and has its appropriate plus or minus sign with it. A second scale on the worm gear shaft is graduated from 0 to 100. Two concentric sets of numerals provide a bidirectional reading capability. A numeral is provided for each 5 MIL increment with single MIL graduations in between numerals. Each numeral in the outer scale has a plus sign to indicate the direction of rotation. This arrangement provides a direct reading capability within one MIL with no magnification. Both scales are made of PMMA with an adjustable metal hub. All characters and graduations are engraved into the PMMA. Prior to engraving, the surface to be engraved is painted white with an overcoat of black or green paint. Green will identify all the numerals and graduations associated with a positive or up rotation of the gimbal and the black will identify the negative or down numerals and graduations. Green and black were chosen for maximum contrast when the characters are illuminated with the red filtered light. To reduce parallax, a fixed index line is located on the inside surface of the window. The scales are adjusted through the bottom of the housing while the unit is separated from the azimuth portion. An alignment fixture precisely establishes a zero elevation reference for scale adjustment, so that the initial zero setting is within 0.2 mr of level.

2.1.4 Leveling Screw/Spring Design

2.1.4.1 Spring Redesign Requirement Summary and Analysis

The existing leveling screw, spring, plate, and Vee-groove retainer plug are not adequate to support the Az-El Head loading. A detail tolerance analysis shows that with the existing pieces, it is possible under worse case for the spring to be loose on the leveling screw and thus not provide any downward force. In addition, it has been determined that if the basic spring configuration were maintained, (supported at both ends instead of cantilevered) unnecessarily high forces would be required to accommodate the overall mechanical range of tolerances. This is due to the inherent high spring rates of a simply supported spring. Figures 2-6 and 2-7 contain all the pertinent dimensions and tolerances of the parts being reviewed.

The problem has been to determine the interference (hence positive clamping) of the 45° spring surface (0.375 diameter of Figure 2-8) to the 0.263 spherical radius of the leveling screw (see Figure 2-9). The tolerance analysis shows that the 0.061 -0.001 spring is essentially clamped in the 0.062 + 0.001 slot in the plate. Some bending will take place over the stiff (0.061 thick x 0.72 lg) portion of the spring and some deflection will take place along the canted 0.031 leg. The spring is confined in the 0.062 slot in such a fashion that the center-line of the spring clamping slot radius (ref. 0.375 dim. of spring) is essentially in line with the center line of the leveling screw, being offset only by the angle of the spring.

Figure 2-9 was generated so that the angle of the clamp and its max - min position on the spherical radius of the screw could be determined. Using the shoulder of the leveling screw as a base (dimension 0.120) it was determined that the position of the bottom of the spring was $0.014 \begin{smallmatrix}+0.013\\-0.015\end{smallmatrix}$ above the shoulder and the angle of the spring varied from 6.51° to 5.31°.

β represents the offset of the bottom of the spring above or below the shoulder of the leveling screw. The worse case (maximum unloading) occurs at the maximum angle α and lowest position of shoulder of screw which is designated γ.

$$\therefore \delta = 0.375 \tan 6.5^{\circ} = 0.042$$

$$\beta = \delta - \gamma = 0.042 - (0.028 \begin{smallmatrix}+0.013\\-0.015\end{smallmatrix}) \cong 0.014 \begin{smallmatrix}+0.013\\-0.015\end{smallmatrix}$$

At the minimum tolerance condition $0.014 - 0.015 \cong 0.0$

the max. distance $\epsilon = 0.120 + \beta \max + 0.061$

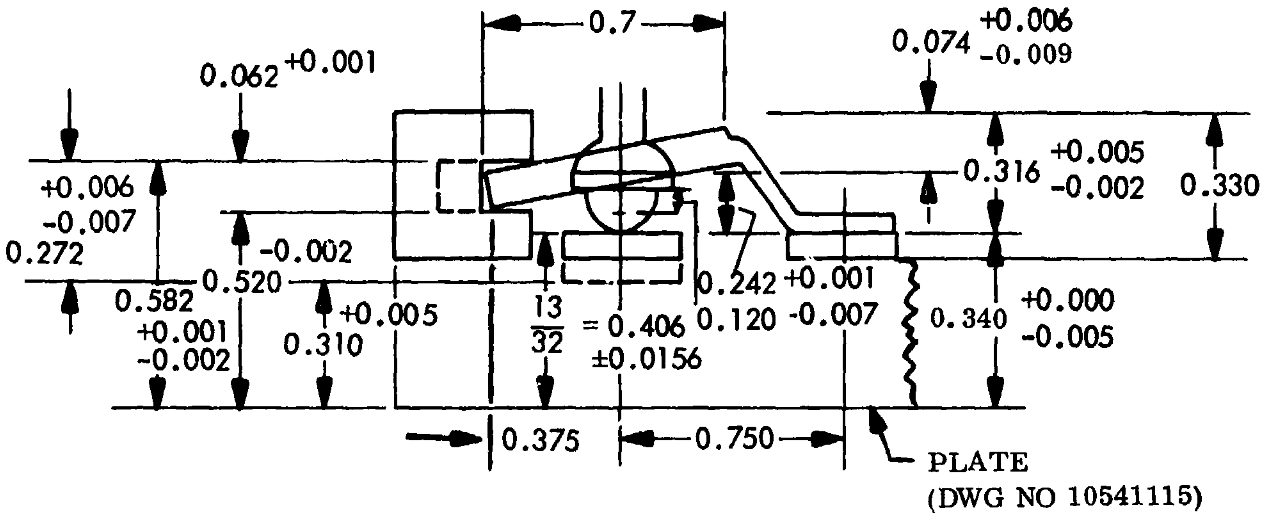


Figure 2-6. Spring, Screw, Plate Assembly

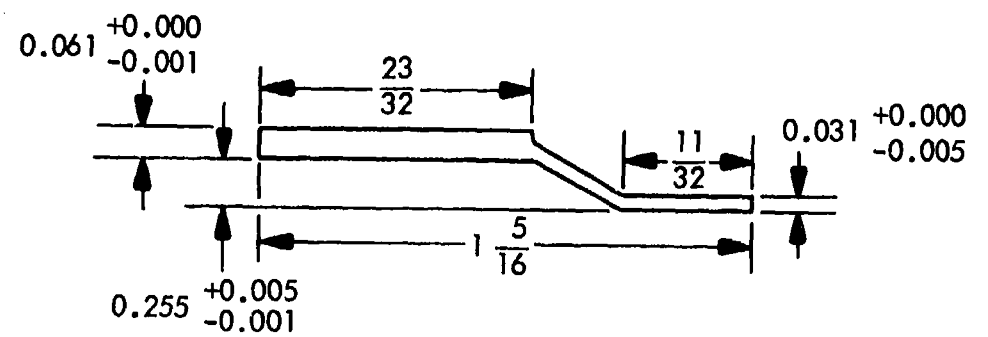
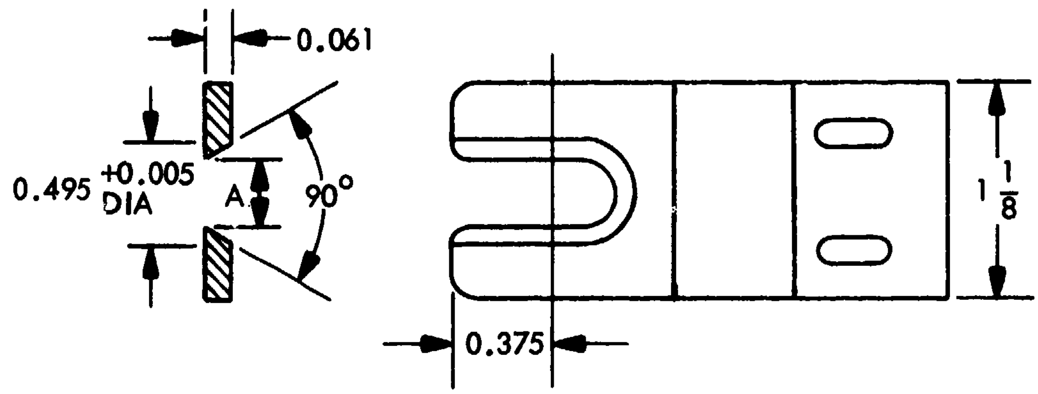


Figure 2-7. Spring (Ref. Dwg. No. 10541157) - Part 1.



A = 0.373

Figure 2-8. Spring (Ref. Dwg. No. 10541157) - Part 2

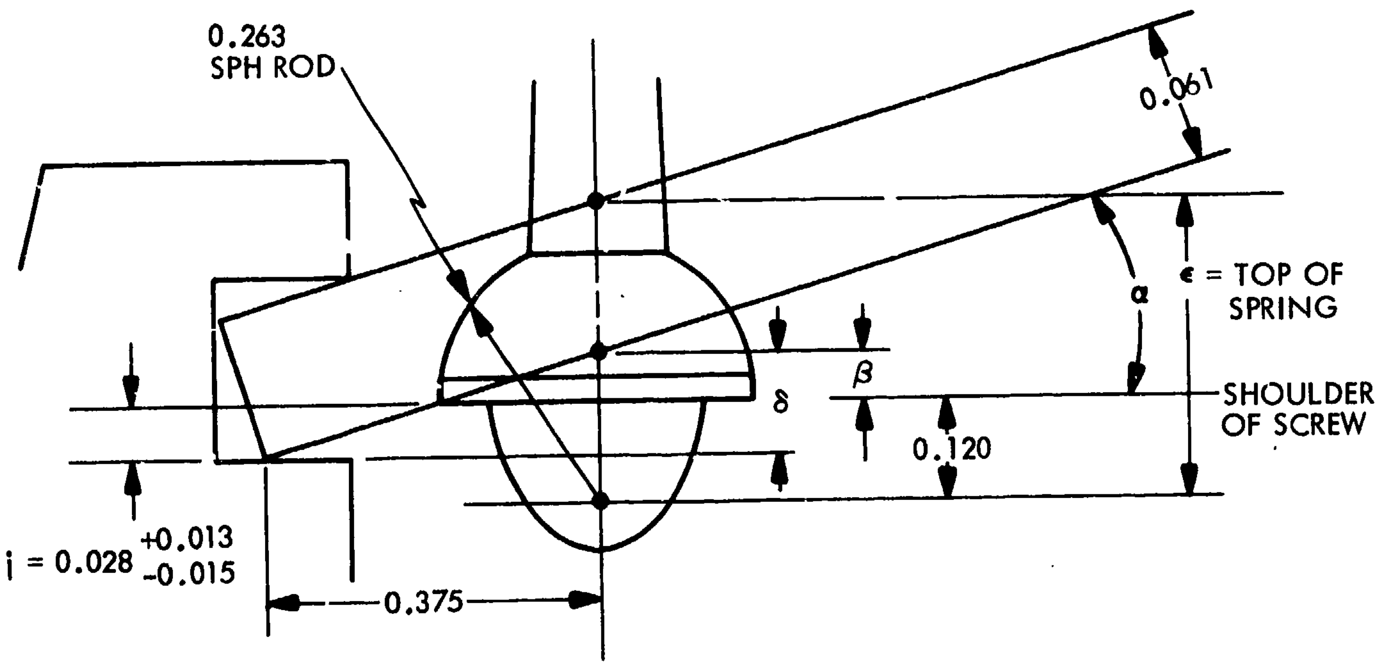


Figure 2-9. Clamp Analysis

$$\epsilon = 0.120 + 0.027 + 0.061 = 0.208$$

$$h = 0.263 - 0.208 = 0.055$$

From the tables of Dimensions of Circular Segments

$$\frac{h}{r} = \frac{0.055}{0.263} = 0.209 \cong 75^{o}$$

$$\frac{c}{r} = 1.224$$

$$\therefore C = 0.263 \times 1.224 = 0.322$$

Since the spring slot dia. of 0.373 is greater than the diameter of the leveling screw ball at the point of tangency, it shows that the spring is not contacting the ball and thus will not exert a downward pressure on the leveling screw.

To find the opposite (loaded condition)

$$\epsilon = 0.120 + \beta \min + 0.061$$

$$= 0.120 + (00) + 0.061$$

$$= 0.181$$

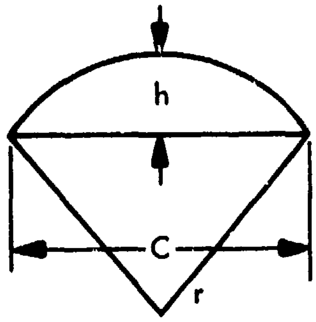
$$h = 0.263 - 0.181 = 0.082$$

$$\frac{h}{r} = \frac{0.082}{0.263} = 0.312 \cong 93^{o}$$

$$\frac{c}{r} = 1.45 \therefore C = 0.263 \times 1.45 = 0.381$$

Since the hole of the clamp is 0.373" dia. and is thus smaller than the diameter of the spherical surface at the calculated point of contact, it indicates that the spring touches the surface and must deform thereby providing the necessary clamping action.

The worse case looseness calculation results in a vertical displacement of approximately 0.021" as shown below:



For C = 0.373 (Ref. Dimensions of Circular Segments)

$$\frac{c}{r} = \frac{0.373}{0.263} = 1.418 \cong 90^{o}$$

$$\frac{h}{r} = 0.293 \therefore h = 0.0771$$

h is the distance from the top of a ball of radius 0.263 to the point where the diameter of the ball is 0.373.

For C = 0.322

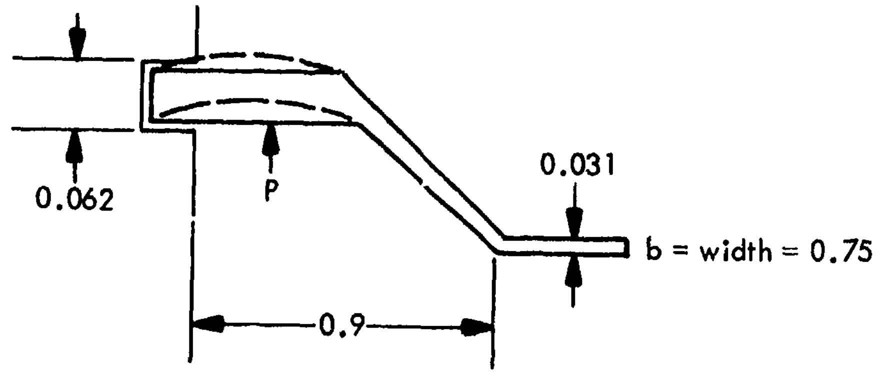
$$\frac{c}{r} = \frac{0.322}{0.263} = 1.224 \cong 75^{o}$$

$$\frac{h}{r} = 0.212 \therefore h = 0.0558 =$$ distance from top of ball of radius 0.263 to the point where diameter is 0.322.

$\Delta h = 0.0712 - 0.0558 = 0.0213$

Thus to insure that the screw is always positively clamped under worse case tolerances would require placing the screw/spring closer together by at least 0.0213 inches.

Under normal manufacturing tolerance accumulations of $\pm$ 0.015 or a total of 0.030", the present design will impart substantial loading on the screw: For example, under minimum tolerances the spring must deform somewhat in order to exert a downward force on the leveling screw. At the other extreme of tolerances, the spring must deform an additional 0.030" ($\pm$ 0.015) and results in the following forces.



For simple supports Load $P = \dfrac{4f\ Ebt^3}{L^3}$

Some of the deflection is taken by the stiff 0.062 member and some by the 0.031 canted member. An approximation as to the magnitude of the load exerted by a 0.030" deflection situation will be to analyze the spring first as if the total beam was 0.062 thick, then if 0.031 thick. The real load is in between the two values.

Thus, Force $P = \dfrac{4f\ Ebt^3}{L^3}$

Case I (Thickness is 0.06)

$$P = \frac{(4)\ (0.030)\ (30x10^6)\ (0.75)\ (0.06)^3}{(0.9)^3}$$

$$= 802\#$$

Case II (Thickness is 0.03)

$$\therefore P = \frac{(4)\ (0.030)\ (30x10^6)\ (0.75)\ (0.03)^3}{(0.9)^3}$$

$$P = 100\#$$

Actual load is somewhere between 802 and 100 # with an average of 300 - 400 # appearing quite likely. These types of loads can not be tolerated due to the extremely high Hertzian stresses that will result. A soft cantilever spring, with a low spring rate is needed to accommodate the assembly tolerances and keep spring forces manageable. A one-piece, three branch spring has been designed to replace the three individual springs of the Adapter Mount (10541111). This design is discussed in Section 2.1.4.2.

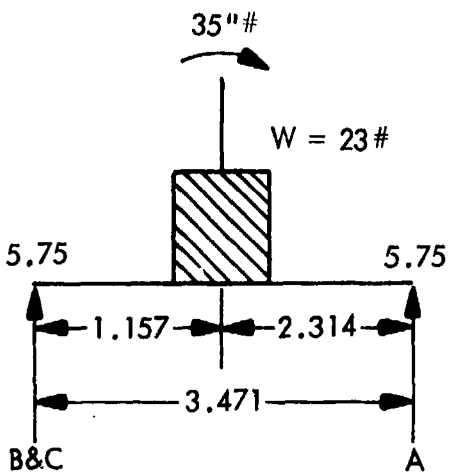
2.1.4.2 New Spring Design

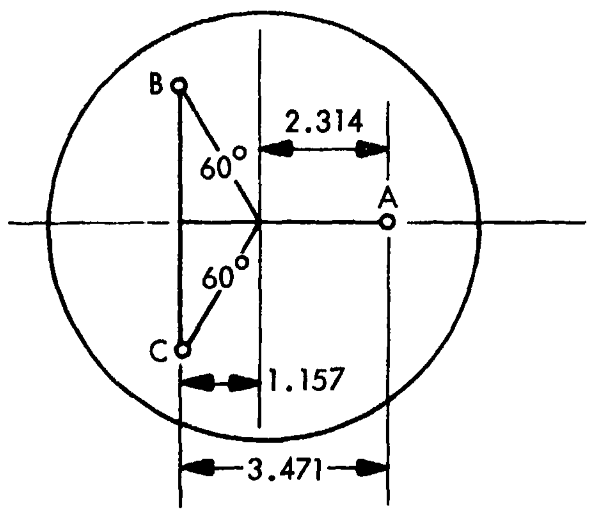
The design of the one piece cantilever spring is predicated on the need for a spring with a fairly low spring rate so that the variation in spring force is minimized over a reasonable range of assembly tolerances.

2.1.4.2.1 Forces on Leveling Screws

The AZ-EL Head will experience loads about the leveling screw/Vee-Block points due to a 35 in. lb overturning moment and the moment generated about the leveling screws due to the system weight which will act approximately through the center of the azimuth ring. This weight is shown below for the two payload conditions.

	System A. HHLR and NVD	System B. HHLR Alone
AZ-EL Head (minus tripod interface) 10.76-1.00 (estimated)	9.76	9.76
HHLR	5.00	5.00
NVD	8.2	—
System Weight	22.96 lbs≈23 lbs	14.76 lbs





For System A

In Case I two leveling screws are in line and moments are taken first about point A to determine the spring force needed at B and C to keep the leveling screws in contact with the Vee-Grooves.

$$\Sigma M_A = 35''\# - 23\# \times 2.314'' + F_T \times 3.471 = 0 \quad (F_T = F_B + F_C)$$

$$F_T = 5.25\#$$

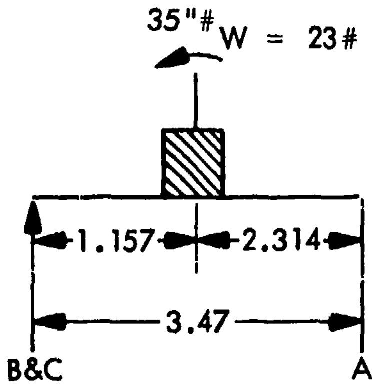
$$F_T = F_B + F_C \therefore F_B = F_C = \frac{5.25}{2} = 2.625 \quad \text{Spring Force} \downarrow$$

Moments are next taken about points B and C, which are in line, to represent the worst loading conditions. In this case the one leveling screw and Vee block at point A must resist both moments about B and C.

$$\Sigma M_{B\text{-}C} = 23\# \times 1.157'' + 35''\# - 3.47\, F_A = 0$$

F_A = 17.75 lb. load acting down on point A.

In Case II the direction of the 35 in. lb. load is reversed to determine what the ma ıum spring force must be in order to hold the screw at point A firmly in contact with the Vee-block.



$$\Sigma M_{B\&C} = -35''\# + 1.157 \times 23\# + 3.47 \times F_A = 0$$

$$F_A = 2.41 \qquad 2.41\# \downarrow \text{ Spring Force Req'd.}$$

Moments are next taken about point A and $F_B + F_C = F_T$

$$\therefore \Sigma M_A = -35^{in.\#} - 23\# \times 2.314'' + 3.47\ F_T = 0$$

$$F_T = 25.4\#$$

$$\therefore F_B = F_C = \underline{12.7\# = \text{load on Vee Groove}} \downarrow$$

For System B

Case I

$$\Sigma M_A = 35 - 14.76 \times 2.314 + F_T \times 3.471 = 0$$

$$F_T = -0.24\# \qquad \text{(downward spring force)}$$

$$F_B = F_C = -0.12\#$$

$$\Sigma M_{B-C} = 14.76 \times 1.157 + 35 - 3.47\ F_A = 0$$

$$F_A = 15\# \text{ load acting down on point A}$$

Case II

$$\Sigma M_{B\&C} = -35 + 1.157 \times 14.76 + 3.47\ F_A = 0$$

$$F_A = 5.16 \text{ (spring force required)}$$

$$\Sigma M_A = -35 - 14.76 \times 2.314 + 3.47\ F_T = 0$$

$$F_T = 19.93\#$$

$$F_B = F_C = 9.97\# \text{ (load on Vee groove)}$$

Thus the worst case requirements are:

Spring load (from System B, Case II)	=	5.16 lbs
Moment load on Vee Groove (from System A, Case I)	=	17.75 lbs
Total load on Vee Groove		22.91 lbs

2.1.4.2.2 Spring Design Analysis

As shown in Section 2.1.4.2.1 a maximum spring force of 5.16 lbs is required to keep the leveling screw in place under worse case conditions. The actual spring force necessary is greater than 5.16 lbs to accommodate assembly tolerances. The magnitude of the force is a function of the spring constant and these tolerances. An assumption of 8 lbs is used for initial calculations.

The geometry of the spring is basically dictated by the shape of the plate (F.A. Dwg. 10541115) and is shown in Figure 2-10.

The deflection y of a flat cantilever spring is

$$y = \frac{4L^3P}{Ebt^3}$$

where

L = length of the cantilever = 1.3"

P = Spring force = 8.0#

b = Spring Width = 1.1"

t = Spring thickness

E = Mod. of elasticity = 30×10^6 psi

$\therefore y = \dfrac{2.13 \times 10^{-6}}{t^3}$ and by varying the thickness of material the following results were obtained.

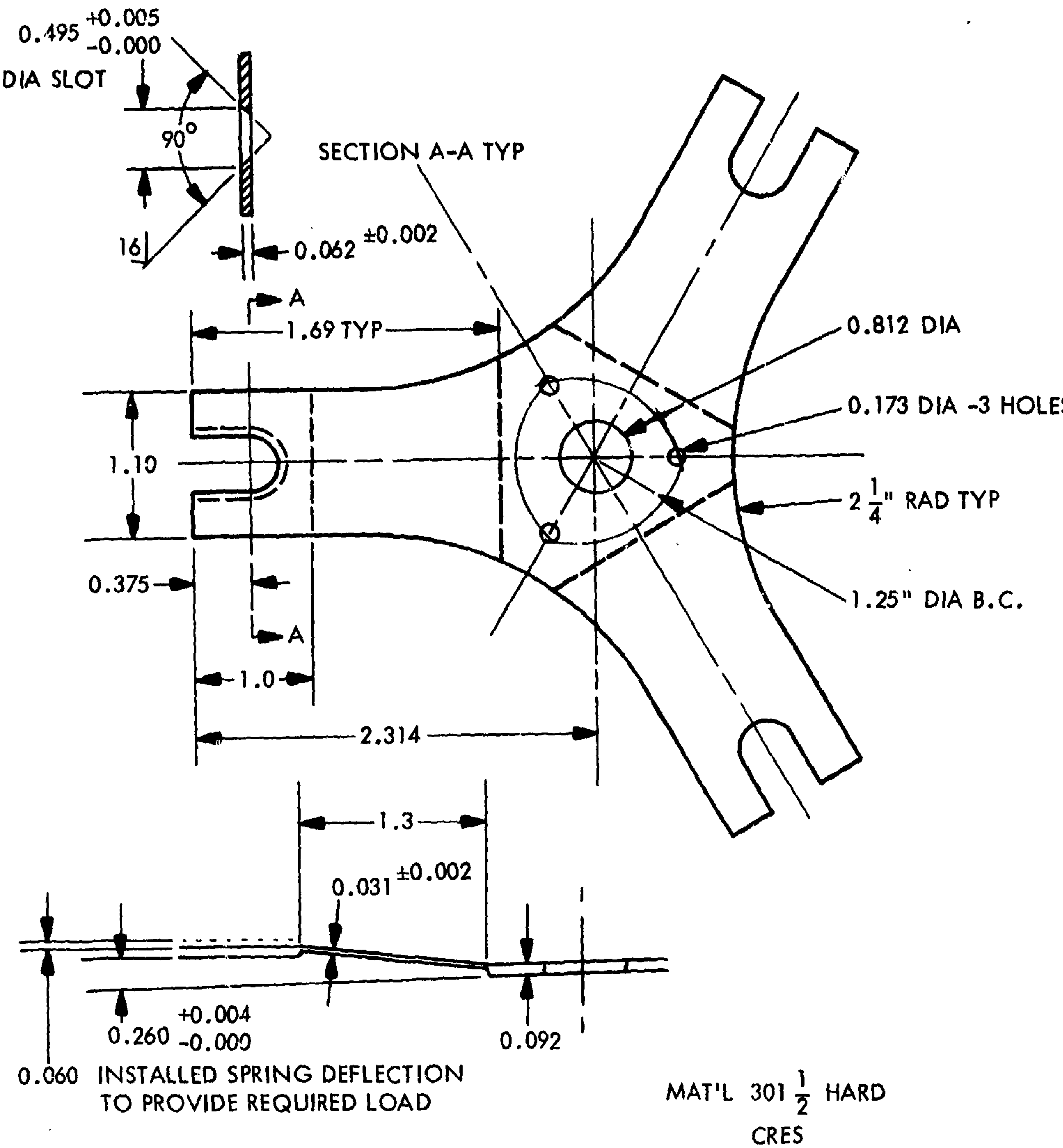


Figure 2-10. Cantilever Spring

Thickness t (in)	Deflection y (in)	Spring rate k (#/in)	Variation in Force Due to ± 0.015 Variation in Deflection
0.025	0.136	58	0.87
0.030	0.074	108	1.62
0.032	0.065	123	1.84
0.036	0.042	186	2.79
0.040	0.033	240	3.6

If the initial deflection of an 0.032 thick spring is changed from 0.065 to 0.060 the spring force will be 7.4 $\pm$ 1.8 lbs for a variation of $\pm 0.015''$.

Spring Stress

The stress induced into a cantilever-type flat spring is defined by

$$\sigma = \frac{6PL}{bt^2}$$

where

P = load = 9.2 lbs (worse case)

L = length of cantilever = 1.3"

b = Spring width = 1.1

t = thickness = 0.032

σ = 63,800 psi

For 300 1/2 H steel

σ_y = 110,000 psi $\quad \therefore$ f of s = 1.7

σ_{ut} = 150,000 psi

2.1.5 Fiber Optics Illuminator

2.1.5.1 Design Considerations

The requirement is to provide a system for illuminating various readout dials and levels on an AZ-EL Head. Because of the spatial and power constraints and the distribution of the various devices to be displayed, it was decided to use a small tungsten lamp in a cylindrical cavity whose interior walls are diffusely reflecting and into the other end of which is inserted a fiber optics bundle with several branches arranged so that each device to be displayed could be conveniently reached and illuminated by an appropriate branch.

(1) Lamp

The lamp selected is a Chicago Miniature with the following characteristics: Design volts 3; Design current 0.19 amp; MSCP 0.25; life 350 hrs.

(2) Fiber Optics

Characteristics:

(a)	Fiber Diameter	40 microns
(b)	Acceptance Angle	60°
(c)	Numerical Aperture	≈ 0.5
(d)	Attenuation	5% per ft.
(e)	Temperature	$-70^{\circ}F$ to $+200^{\circ}F$
(f)	No. of Bundles	4: - each end ferruled and polished.

(3) Cavity

Cylindrical: Inside painted with Eastman Kodak paint #6080, white reflectance paint. Reflectance 0.99; 0.2u to 2.5u.

(4) Power Source

Battery.

(4) Magnifiers

One; 2X

2.1.5.2 Calculations of Luminance of Fiber Optics

2.1.5.2.1 Computation of Luminance, B, from Lamp and Cavity

There are two components of light flux to the fiber bundle face.

(1) Direct; that is, from lamp considered as point source

(2) Indirect from diffusely reflecting interior walls of cavity.

Direct Component

The intensity I, of the lamp = 0.25 MSCP

Distance γ, of lamp to bundle surface = 0.5 cm

Acceptance angle of bundle = 60°

Angle of edge rays from lamp to bundle $\approx 22^{\circ}$.

Therefore, all direct rays from lamp to bundle face within acceptance angle of bundle are transmitted except for reflection losses at bundle face.

Flux F from lamp is $F = 4\pi I = 4\pi 0.25$ lumens.

$$\text{Luminance B of bundle} = \frac{I A_b}{\gamma^2 \Omega_a} = \frac{0.25 \times 0.1257}{0.25 \times 0.842} = 0.1493 \text{ stilb}$$

where $\gamma = 0.5$ cm

where F_o is flux arriving at surface $= 4\pi I$

Ω_a is solid angle corresponding to acceptance angle $= 2\pi(1 - \cos\theta)$

$2\pi(0.134) = 0.842$ s.r.

A_b, area of bundle surface $= 0.1257 \text{ cm}^2$

$$\text{Luminance B} = \frac{I A_b}{\gamma^2 \Omega_a} = \frac{0.25 \times 0.1257}{0.25 \times 0.842} = 0.1493 \text{ stilb}$$

A_b = Area of bundle = $\pi \times 0.04 = 0.1257\ cm^2$

T_b = Transmittance of bundle face ≈ 0.9

The bundle is divided into four branches. Assume that flux is equally divided. Then the longest bundle is about six inches. The transmission T_O, through that bundle for attenuation of 0.05 $feet^{-1}$ is $1 - 0.05 \times 0.5 = 0.975$.

Luminance of longest bundle is thus

$$\frac{B}{4} T_o T_b T_f = 0.037322 \times 0.9753 \times 0.81 = 0.0295 \text{ stilb.}$$

T_f = transmission of red filter = 0.9

This is the luminance available for illuminating the Az disk. The graduations on the disk are 0.010 inches wide. Thus, the subtending angle for normal seeing is 10^{-3} rad. The eye resolution is about 1 to 3 arc minutes when the luminance range is 3 to 10^{-4} stilb.[1]

A magnifier of power ≥ 2 is therefore, adequate. From the above computation it shows that the direct output of the lamp alone supplies, at the pertinent bundle, a radiance of 2.95×10^{-2} stilb which is about 1 or 2 orders greater than that required for limiting eye resolution. This luminance, in turn, illuminates a cavity whose interior, except for the magnifier is diffusely reflecting, of reflectance ≈ 0.99. Consequently, the luminance B_f of the field in which the graduated disk and vernier are situated is

$$B_f = 2.9205 \times 10^{-1} \text{ stilb}$$

This value of luminance is within the range for the resolution limit of the eye.

2.1.5.2.2 Computation of Indirect Component of Radiance Due to Diffuse Reflectance of Lamp Cavity

In order to determine the component of luminance due to the reflecting cavity, it is assumed that since all the flux emitted by the lamp is multiply reflected, except that which is exited at the fiber optics bundle, the cavity could, to a first approximation, be considered as a sphere having diffusely reflecting

(1) Boutry, G.A. Instrumental Optics, Interscience Publishers, Inc., N.Y. 1962.

interior walls with a light source at or near the center. In this case the radius of the sphere is taken as the distance from the lamp filament to the fiber surface. The problem of computing the luminance of an incomplete spherical cavity with diffusely reflecting interior walls has been worked out by Miller and Sant[2].

Following the procedure given in that article, one finds that the luminance B is given as:

$$B = \frac{F_o R^2}{\pi A\,[1 - \alpha R]}$$

where F_o is the source flux

R is the reflectance

A is the area of the sphere surface

$$\alpha = \frac{A-a}{A}$$

a = the area of holes or non-reflecting regions in the sphere.

Substituting the values into (2) gives

$$B = \frac{4\pi I_o R^2}{\pi(4\pi r^2)\left[1 - \frac{(4\pi r^2 d^2)}{16\, r^2}\right]}$$

where I_o = MSCP = 0.25 candle

r = radius of sphere = 0.2 cm

d = diameter of fiber optics bundle = 0.5 cm

On substitution of values into equation one gets, attenuation included

B = 0.15030 stilb for complete bundle

---

(2) Miller, O. E. and A. J. Sant. JOSA 48, 11, 828, 1958.

For each of 4 bundles

$$B = 0.0376$$

With attenuation the luminance of 6 inch fiber due to this component is

$$B\,T_o T_f T_b = 0.0376 \times 0.9753 \times 0.9 \times 0.9 = 0.0297 \text{ stilb.}$$

2.1.5.3 Conclusion

The foregoing analysis shows that the method of illumination provides adequate luminance for an observer to read the various dials and displays.

The necessary optical component is a magnifier of about 2X for reading the azimuth dial and vernier. For the elevation readout, no magnifier is necessary since the size and luminance of the characters are such that the latter would be unambiguously readable with the unaided eye.

2.1.6 Power Source

2.1.6.1 Battery Selection

The battery selected for scale illumination is the BA-3202, which is a 1.5V, Alkaline, D-cell. The D-cell was chosen since it is more readily obtainable in the field. The alkaline battery was chosen for its higher capacity at low temperatures as compared to the carbon-zinc type.

2.1.6.2 Battery Life

Battery life is determined in the following discussion. Scale illumination on-time for one mission is assumed below:

(1) Leveling time = 120 sec
(2) On time per ranging function = 30 sec
(3) Number of rangings at each location = 10

The total on time per mission is therefore,

$$T_{on} = 120 \text{ sec} + 10 \text{ (30 sec)} = 420 \text{ sec} = 0.117 \text{ hr}$$

The lamp draws 190 ma when on. The capacity required from the battery is therefore,

$$C_{req} = 190 \text{ ma} \times 0.117 \text{ hr}$$
$$= 22 \text{ ma-hr}$$

The available battery capacity at 70°F and 190 ma load current is approximately 40 hours or 7600 ma-hr.

The total number of missions from the battery is therefore:

$$\text{Number of missions} = \frac{\text{available capacity}}{\text{required capacity/mission}}$$

$$= \frac{7600 \text{ ma-hr}}{22 \text{ ma-hr/mission}}$$

$$= 345 \text{ missions.}$$

At -40°F the battery capacity is 190 ma-hr. The number of missions possible is:

$$\text{Number of missions at} -40^{o}\text{F} = \frac{190 \text{ ma-hr}}{22 \text{ ma-hr/missions}} \approx 9$$

It is assumed that for cold weather applications, the operator will carry the batteries in his clothing. The temperature of the battery under these conditions is assumed to be +40°F. The available battery capacity at 40°F is approximately 4750 ma-hr. The number of missions available from the battery is:

$$\text{Missions at } 40^{o}\text{F} = \frac{4750 \text{ ma-hr}}{22 \text{ ma-hr/mission}} = 215 \text{ missions}$$

This number is somewhat optimistic due to further cooldown of the battery after installation.

2.1.7 Environmental Considerations

During normal transportation, the AZ-EL Head is protected from shock loads by its carrying and transit cases. However, in field use the operator may relocate the AZ-EL Head while it is mounted to the Tripod. Therefore shock loads may be induced in the Head during emplacement. For this type of shock input, principal stresses are in two areas: (1) compressive stress in the leveling screw, and (2) tooth load in the elevation drive.

Although the calculations are not presented in this document, it can be shown that a 3g shock input along the azimuth axis would increase the compressive stress on the leveling screw Vees to 1.15 times the design load. Although, the design limit was taken as 75% of yield, this might produce slight brinelling which, in turn, might affect ease of leveling. However, any shock loads due to emplacement will be attenuated by the high compliance of the tripod legs. Without knowing the parameters of emplacement loads, a quantitative result cannot be given. Qualitatively, the shock response of the AZ-EL Head should be low and within the allowable limit of Brinelling.

The static load capacity of the elevation drive gear is 725 inch-pounds. This is more than adequate to resist anticipated shock loads.

Protection against humidity, water immersion, dust, salt fog and fungus is provided by careful selection of materials and the sealing of the elevation housing. "O" rings are used for static seals and graphite filled teflon Bal-Seals for the rotating seals. Seals provide several advantages. First, any foreign material between the spur and worm gear would result in a positional error and adversely effect the wear characteristics of both gears and bearings. Second, if the housing were allowed to breath, a possibility of condensation on the window would exist. And, third, moisture and salt would contaminate the grease and promote corrosion or pitting on the gear teeth.

The azimuth portion of the AZ-EL Head remains unsealed, since it has been qualified as a non-sealed unit Azimuth position accuracy is obtained from the direct reading azimuth scale, and is independent of the drive. Therefore, foreign material, pitting, wear, or corrosion will not affect accuracies.

2.2 TRIPOD MODIFICATION

The Tripod Assembly 10541078, will be modified for use with the AZ-EL Head. This modification will include increasing the tripod base circle from 15 to 20.8 inches (see Figure 2-9) and removing the battery support clips from one of the tripod legs. The tripod base circle is being increased to provid· improved stability to the AZ-EL Head Assembly for the condition in which the NVD is mounted alone during installation. Figure 2-2 shows the combined G.C. of the AZ-EL Head and the NVD with respect to the 15 inch and 20.8 inch base circles. With a 20.8 inch base circle, the tripod will withstand a 23.6 inch-lb overturning moment.

The larger base circle is incorporated into the design by machining an additional 11.5^{o} of material from the stop face of each tripod leg adapter 10541083.

2.2.1 Tripod Interface

A drawing check has been completed on the interface between the tripod and the payload baseplate. During this drawing check, it was noted that the spacer plate on the tripod 10541098 did not conform to the drawing for that part. A tolerance study indicated that if the spacer plates were made to print, that a maximum-to-minimum interference between the spacer and gear camlock 10541135 would exist. This interference would be 0.018 inches. A change notice has been prepared for the spacer plate to eliminate this potential interference. The data generated for this change is shown in Section 8.3.

2.2.2 Tripod Structural Analysis and Tests

Structural analysis and tests have been completed on the present tripod configuration and on the tripod as modified per Section 2.2. The analysis was based on an AZ-EL payload weight of 30 pounds. The assumption was made that this weight will be equally distributed to each tripod leg. The angle between the tripod interface base plate and tripod legs at present is 20°. This angle will be 31.5° following tripod modification. Maximum deflection calculations and test results, as well as stress calculations are included on the following pages. This data is summarized in Table 2-1.

Table 2-1. Maximum Deflection and Stress Calculation Summary

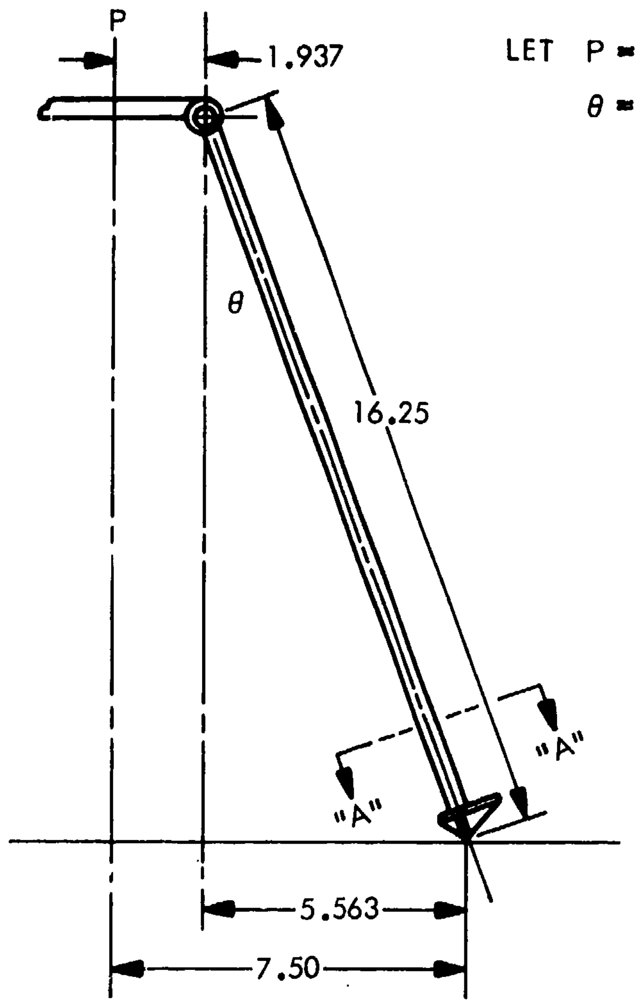
Description	15 inch base circle	20.8 inch base circle
Calculated Deflection with legs retracted	0.109 in.	0.166 in.
Measured deflection with legs retracted	0.090 in.	0.126 in.*
Calculated deflection with legs extended	0.314 in.	0.479 in.
Calculated bending stress with legs retracted	4703 psi	7179 psi
Calculated bending stress with legs extended	6693 psi	10,216 psi

*Data taken on a 21.6 inch base circle

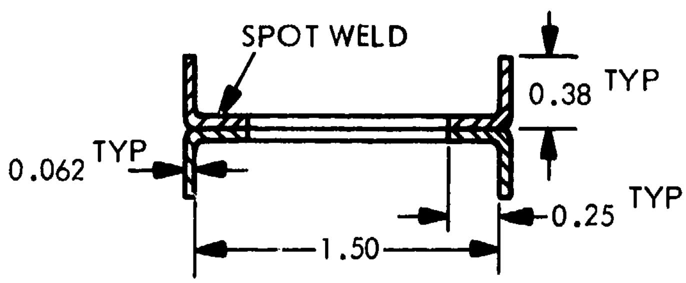
The analysis and test results indicate that no structural problems are anticipated in the tripod assembly.

2.2.3 Tripod Structural Analysis

2.2.3.1 Present Configuration

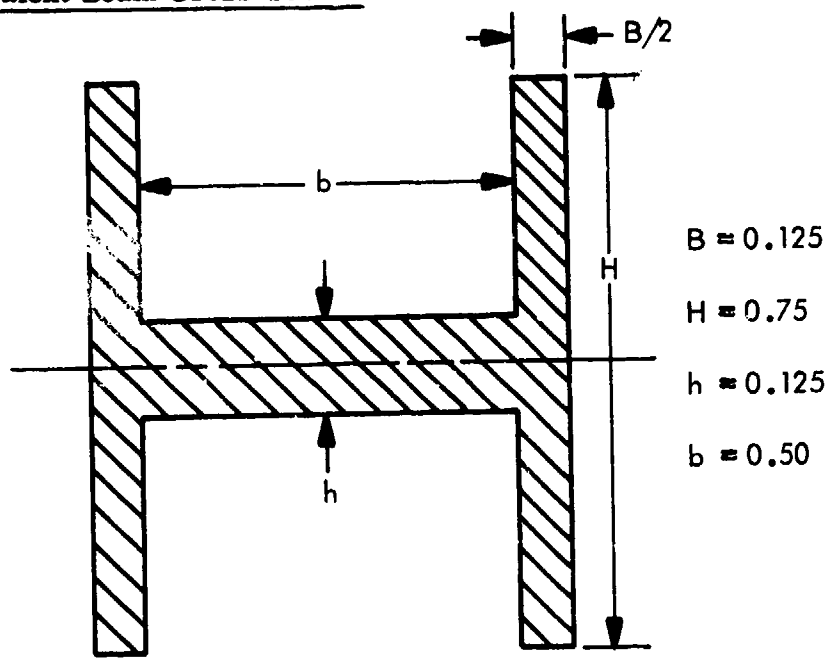


LET P = 30 LBS
$\theta = 20°$



MAT'L : ALUM
E = 10,000,000 IN^4

2.2.3.2 Equivalent Beam Cross-Section



$$I = \frac{BH^3 + bh^3}{12}$$

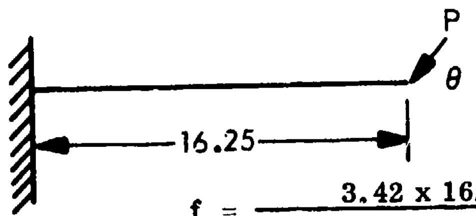
$$I = \frac{0.125 \times 0.75^3 + 0.50 \times 0.125^3}{12}$$

$$I = \frac{0.053 + 0.00098}{12}$$

$$I = 0.00449 \text{ IN}^4$$

Max Deflection:

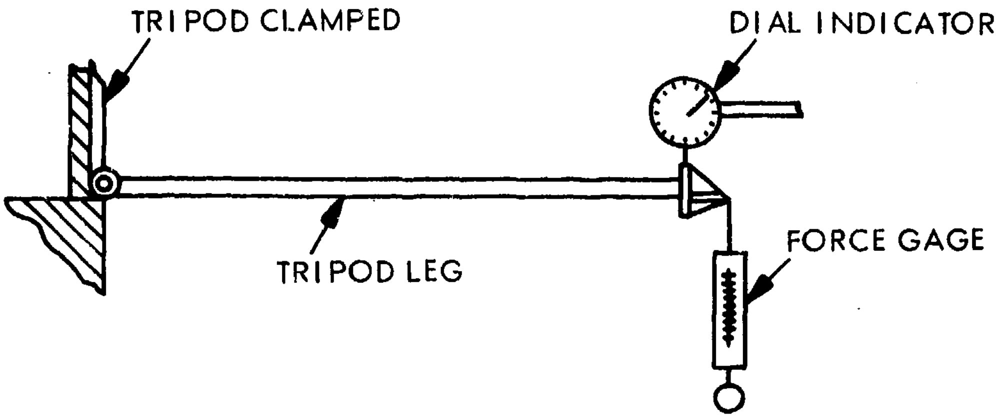
P = 10 sin 20 = 3.42 lbs.

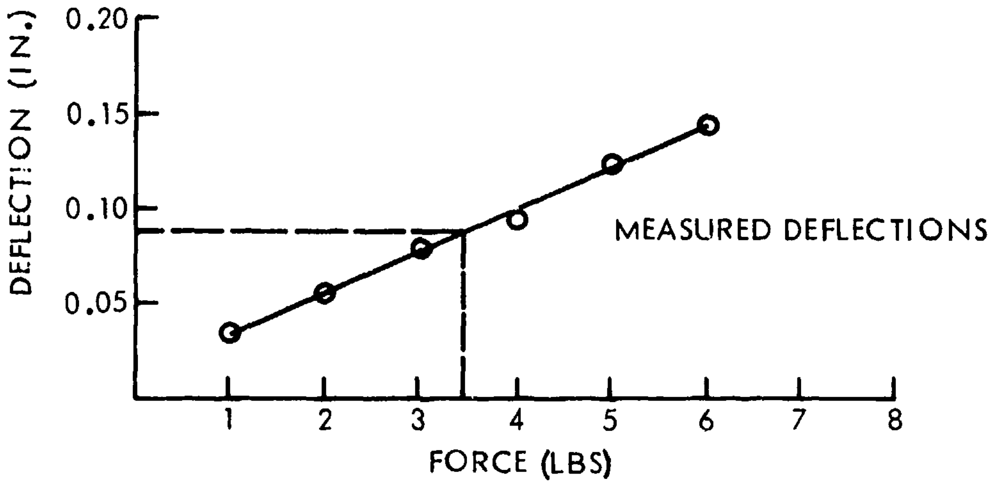


$$f = \frac{PL^3}{3EI} \qquad f = \frac{3.42 \times 16.25^3}{3 \times 10,000,000 \times 0.00449}$$

$$f = 0.1089 \text{ IN}$$

2.2.3.3 Deflection Test and Results





Measured deflection for 3.42 LBS = 0.09 IN and calculated = 0.109 IN

Stress calculation (legs retracted)

Bending Moment:

M = 3.42 LBS x 16.25 IN = 55.58 IN-LBS

C = 0.38 IN

Bending Stress:

$$S = \frac{MC}{I} = \frac{55.58 \times 0.38}{0.00449}$$

$S = 4703\ LBS/IN^2$

Tripod Legs Extend 6.875 IN

Total $L = 16.25 + 6.875 = 23.125\ IN$

and:

$$M = 3.42 \times 23.125 = 79.09\ IN\text{-}LBS$$

$$S = \frac{79.09 \times 0.38}{0.00449}$$

$$S = 6693\ psi$$

Deflection with Legs Extended

$$f = \frac{PL^3}{3EI}$$

$$f = \frac{3.42 \times 23.125^3}{3 \times 10{,}000{,}000 \times 0.00449}$$

$$f = 0.314\ IN$$

Modified Tripod

Angle θ Increased from 20 to 31.5^o

$$p = 10\ LBS \times SINE\ 31.5^o$$

$$p = 5.22\ LBS$$

$$f\ MAX = \frac{5.22 \times 16.25^3}{3 \times 10{,}000{,}000 \times 0.00449} = 0.166\ IN$$

$$M = 5.22 \times 16.25 = 84.83\ IN\text{-}LBS$$

$$S = \frac{84.83 \times 0.38}{0.00449}$$

$$S = 7179\ LBS/IN^2$$

% Increase in Stress

$$\left(\frac{7179 - 4703}{4703}\right) \times 100 = 52.6\%$$

Modified Tripod with Legs Extended

$$f\ MAX = \frac{5.22\ LBS \times 23.125^3}{3 \times 10,000,000 \times 0.00449}$$

$$f\ MAX = 0.479$$

Bending Moment

$$M = 5.22 \times 23.125 = 120.71$$

Bending Stress

$$S = \frac{120.71 \times 0.38}{0.00449}$$

$$S = 10,216\ LBS/IN^2$$

2.3 VISUAL DETECTION

It is required that the equipment not be visually detectable during operation on a moonless night by a fully dark-adapted observer having normal 20/20 vision and at a distance of 25 feet. In order to minimize the possibility of visual detection while still providing a useful instrument, those functions of the AZ-EL Head requiring illumination are illuminated with a red light of variable intensity. The ON/OFF switch is spring loaded and must be held on for illumination. Thus, the only time that the unit is illuminated is while the operator is actually viewing one of the functions that requres illumination.

There is a light source with a red filter enclosed in the AZ-EL Head structure. Light is transmitted via fiber optics to each of the functions requiring illumination (azimuth readout, elevation readout, elevation vernier, and leveling vial). A dimmer is provided so that the operator can adjust the illumination level to the lowest consistent with his need to read these functions. All of the readout functions are on the operator's side of the instrument and are therefore, not directly viewable by an enemy in front of the instrument, or by an enemy within 90^{o} of the line of sight. The leveling vial is recessed and shaded by the fiber optics housing so as not to be viewable by an enemy in front of the instrument. The effects of glare cannot be assessed until a unit is available for evaluation.

2.4 VERIFICATION OF ADAPTER MOUNT DRAWINGS

The engineering review of those drawings of the Adapter Mount (10541111) which will be used for the AZ-EL Head is in process. The review is about 80% complete with approximately 10% of the drawings requiring minor changes. Major changes are required to the leveling screw and Vee, as discussed in Sections 2.1.4 and 3.2.4. A new spring has been designed and is also discussed in Section 2.1.4.

SECTION 5

ACCESSORIES

5.1 CARRYING CASE

5.1.1 Requirements

The carrying case for the AZ-EL Head (AEH) will be lightweight and rain resistant and will properly support the equipment during transport by an individual soldier. It will store an AZ-EL Head, Tripod Assembly and two batteries, and the adapter for the HHLR. The carrying case will be a rugged and lightweight container fabricated from non-nutrient, waterproof materials. A second case will be a simple bag (canvas) which will store the AEH, shelf mount, and two batteries.

5.1.2 Description

The carrying case, see Figure 5-1, will be fabricated from a high impact plastic and will contain the following features:

Exterior:

(1) Extended aluminum ruggedized closure and latch arrangement to assure proper alignment to the case and seal the cover.

(2) A hinged cover to prevent dropping or losing the cover. The separation of the cover and case will be such that the soldier will have proper gripping area in order to remove the AZ-EL Head and other equipment from the case with ease.

Interior:

(1) Support cushions to properly position the AEH and provide some shock isolation.

(2) Cutouts/slots to contain the equipment specified in 5.1.1.

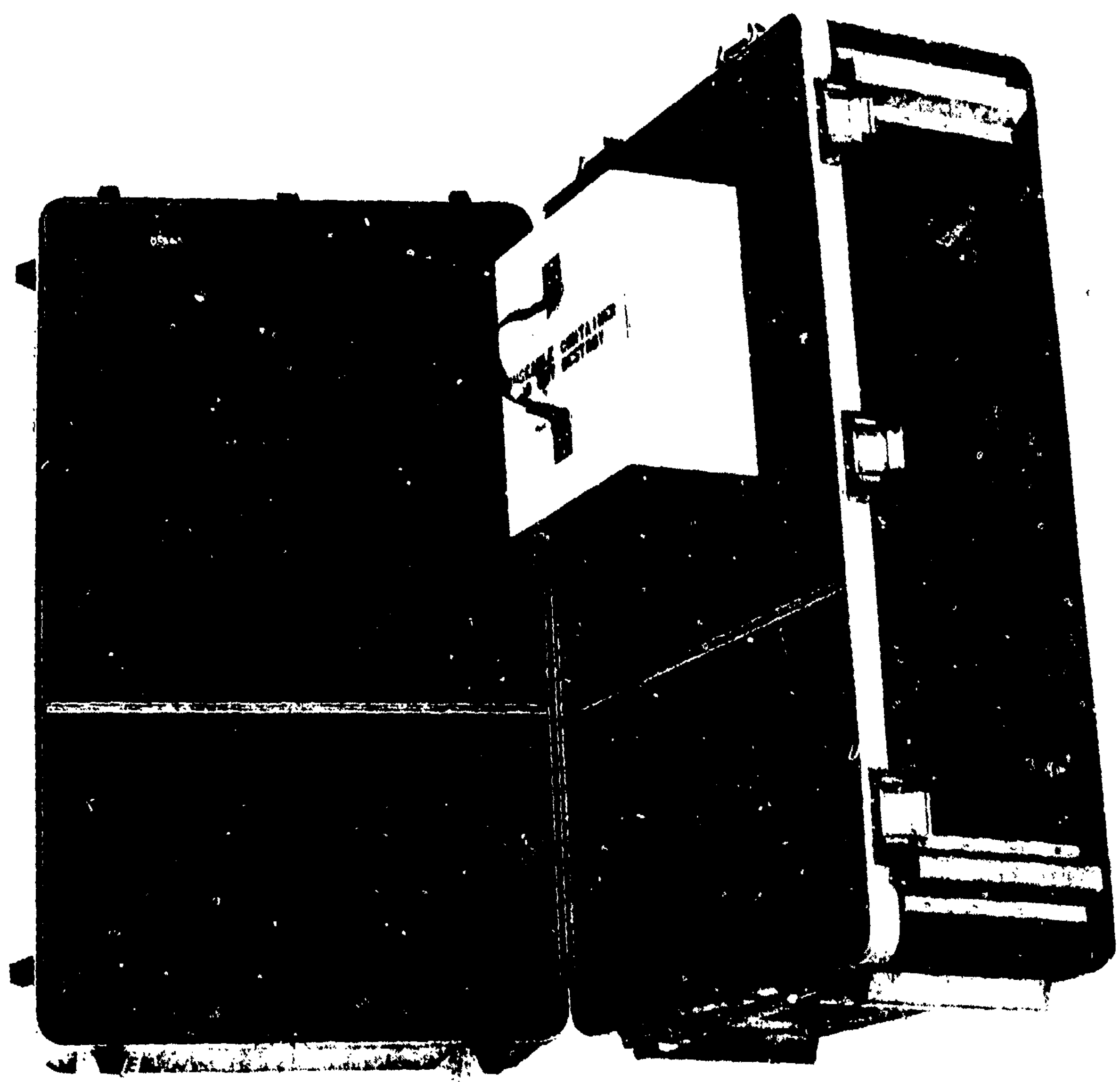


Figure 5-1. Case, Laser Rangefinder Equipment CY-7667( )/GVS-5

5.2 TRANSIT CASE

5.2.1 Requirements

The transit case for the AZ-EL Head of the Hand Held Laser Rangefinder (HHLR) and associated equipment will be of minimum size, and watertight. It is of rugged design to contain and protect the AZ-EL Head during all modes of transportation and storage.

The case will be fabricated from non-nutrient, waterproof materials and will conform to RDD-STD-2 (Cases, Transit and Combination for Electronic Command Equipment). The transit case will have provisions to store the following items:

(1) 1 - AZ-EL Head

(2) 1 - AZ-EL Head carrying case, containing tripod

(3) 1 - AZ-EL Head carrying case, canvas

(4) 2 - Spare Batteries

(5) 1 - Shelf Mount

(6) 1 - Adapter Bracket

The transit case and its support cushions will be capable of meeting the following environmental conditions when in the transit configuration:

(1) Shock - MIL-STD-810B Method 516, Procedure II, (Includes 30" drop test - Maximum Internal equipment response 35 gs)

(2) Vibration - MIL-STD-810B, Method 514, Procedure XI, Part 2

(3) Temperature - 70°F to $+160^{\circ}$F Storage

(4) Immersion - MIL-STD-810B, Method 512 (3 feet of water, 2 hours duration minimum)

(5) Altitude - Ground Level to 50,000 feet. Maintain minimum 2.0 psia within case at 50,000 feet.

5.2.2 Description

The transit case (see Figure 5-2) will conform to the requirements of RDD-STD-2 and will be fabricated from a high impact plastic and/or aluminum.

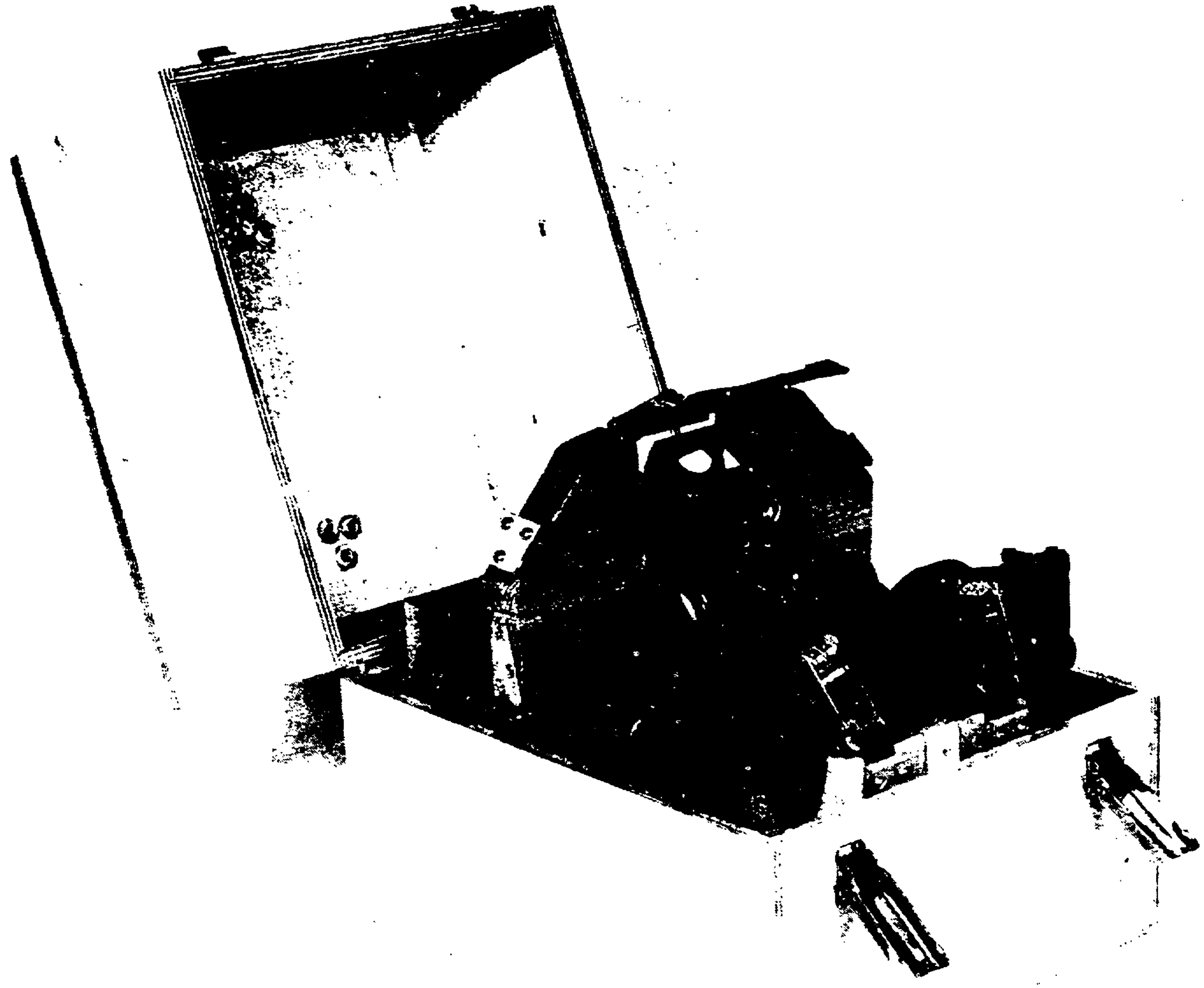


Figure 5-2. Case, Laser Rangefir 'er Equipment CY-7668( )/GVS-5

The following features will be incorporated into the design of the transit case.

Exterior:

(1) Rub rails or equivalent to protect the corners during handling and transportation, latches, handles humidity indicator and pressure relief valve.

(2) Extruded aluminum closure or equivalent to seal the transit case and minimize any distortion.

(3) Spring loaded or mechanical latches on the case to assure a positive seal and watertightness.

(4) A 2.0 psi minimum automatic (2-way) pressure relief valve for air transport. (Pressure differential across the case not to be more than 11 psi at 50,000 feet altitude.)

(5) A manual pressure relief valve to facilitate opening the case. This valve may be incorporated as part of item (4).

(6) Humidity indicator to accommodate method IID pack per MIL-P-116 to minimize frequency of equipment inspections.

Interior:

(1) Support cushions designed to meet the environmental conditions specified in Paragraph 5.2.1.

(a) Cutouts/slots will be provided to contain desiccant and equipment specified in Paragraph 5.2.1.

(b) Hand holes will be provided where necessary to accommodate easy removal of equipment.

(2) Desiccant will be provided for the protection of the items and cushioning during transportation and storage.

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461 COMMANDER, ROCK ISLAND ARSENAL
US ARMY ARMAMENT COMMAND
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473 COMMANDANT
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002 ABERDEEN PROVING GROUND, MD 21005

474 COMMANDER
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001 ABERDEEN PROVING GROUND, MD 21005

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499 COMMANDER
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BLDG 350
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513 COMMANDER
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556 COMMANDER, HQ MASSTER
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001 ALEXANDRIA, VA 22333

563 COMMANDER, DARCOM
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564 CDR, US ARMY SECURITY AGENCY
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568 COMMANDER
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569 COMMANDER
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680 COMMANDER
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